Fermi National Accelerator Laboratory
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Fermilab 85/32
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UC-41

SITE ENVIRONMENTAL REPORT
For Calendar Year 1984

by
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May 1, 1985

Laboratory Work
by
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1. Introduction

This report summarizes the environmental activities and their results at Fermi National Accelerator Laboratory (Fermilab) for Calendar Year (CY-) 1984.

The facility consists of a series of proton accelerators which became operational in 1972, producing higher energy protons than any other accelerator. As a result of accelerator improvements, the original design energy of 200 GeV (billion electron volts) was gradually raised and operation at 400 GeV was routine between 1976 and 1982 using conventional magnets. At that time a ring of superconducting magnets was added which doubled the energy while using less electrical power.

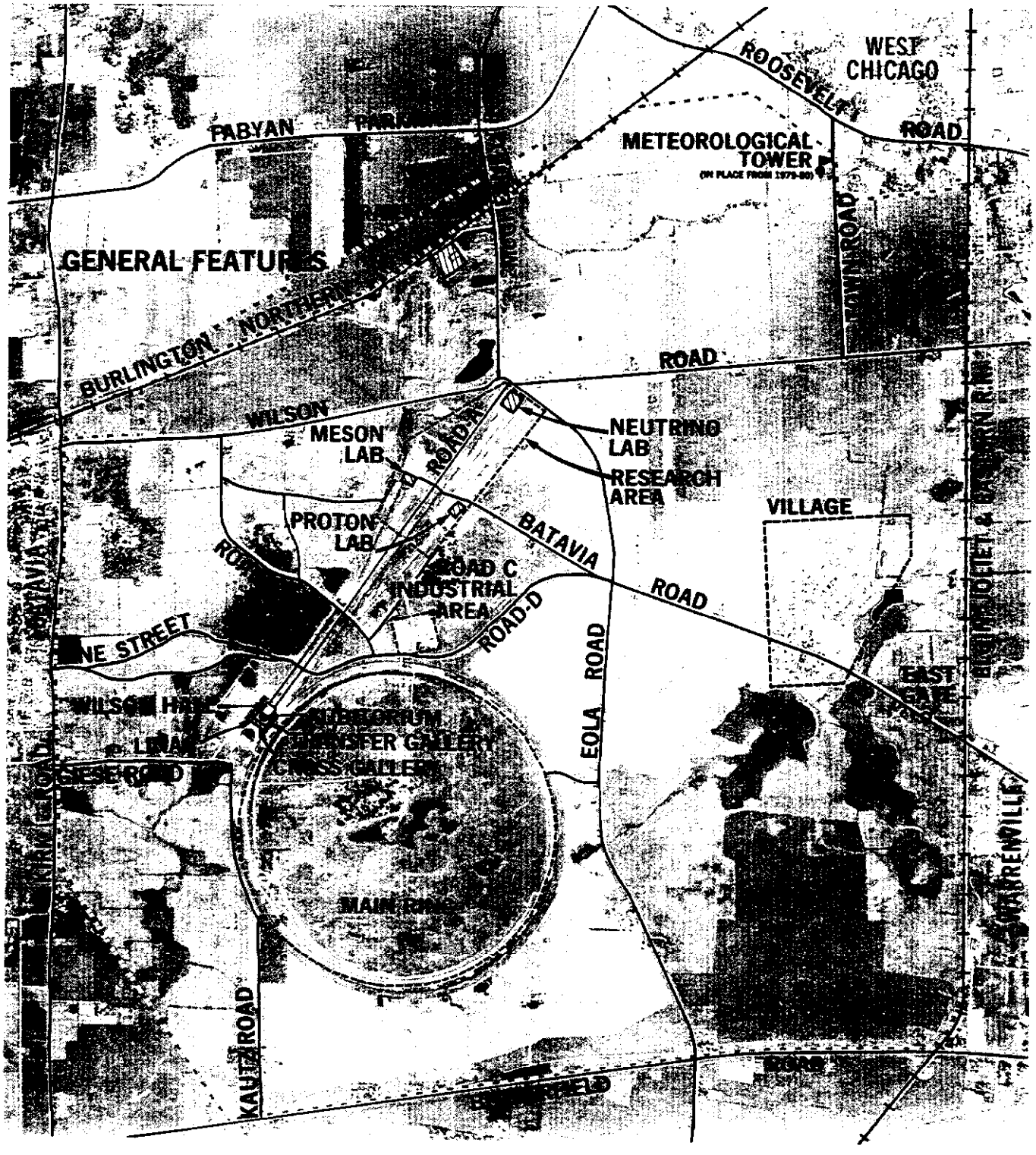
The primary purpose of the installation is fundamental research in high energy physics. At the present time the protons are being extracted from the superconducting synchrotron and directed to fixed targets. Collisions of protons and antiprotons each having 1 TeV (1000 GeV) are planned. The antiproton source is nearing completion as well as a large detector to observe the head-on collisions. In addition, cancer patients are being treated using neutrons released by the interactions of 66 MeV protons from the Linac (linear accelerator), the second stage of the series of accelerators.

The proton beam extracted from the 2 km (1.2 mi) diameter main accelerator is taken to three different experimental areas on site. These are the Meson, Neutrino and Proton Labs located in the Research Area (Fig. 1). All three of these areas received proton beams for the first time in 1972. Radioactivity is produced as a result of the interaction of the accelerated protons with matter. Operation of the accelerator produces some radiation which penetrates the shielding material as well as some airborne radioactivity. Also, some radioactivation occurs in the soil and in the water used to cool beam components. A thorough evaluation has been made of the on-site discharges as well as the potential for off-site releases of radioactive and non-radioactive effluents. An extensive monitoring program is being carried out to verify that radiation exposures as well as non-radioactive releases are far below the permissible limits.

Fermilab is located in the greater Chicago area (Fig. 2) on a 27.5 km^2 (10.6 mi^2) tract of land in an area which is rapidly changing from farming to residential use. There are many municipalities in the vicinity, resulting in a distinct pattern of increasing population concentration toward Chicago to the east (Fig. 3). Within a 3 km (2 mi) distance from the Laboratory boundaries, Batavia (pop. 12,574), Warrenville (pop. 7,519), and West Chicago (pop. 12,550) can be found (Fig. 2).[1] The terrain is relatively flat as a result of past glacial action.

The two major environmental features near the Laboratory are the Fox River to the west, which flows south through Batavia with an average of 1900 million liters (500 million gallons) per day, and the west branch of

Figure 1


WEST CHICAGO
ROOSEVELT
ROAD
FABYAN PARK
METEOROLOGICAL TOWER
(IN PLACE FROM 1979-80)
GENERAL FEATURES
TOWN ROAD
BURLINGTON NORTHERN
ROAD
WILSON
MESON LAB
ROAD A
NEUTRINO LAB
RESEARCH AREA
VILLAGE
PROTON LAB
BATAVIA
ROAD C
INDUSTRIAL AREA
ROAD
ROAD D
EOLA ROAD
EAST GATE
MAIN RING
KAUTZ ROAD
OVERLAY FOR BASE 4, FERMILAB
PREPARED IN 1982
FERMI NATIONAL
ACCELERATOR LABORATORY
DOE

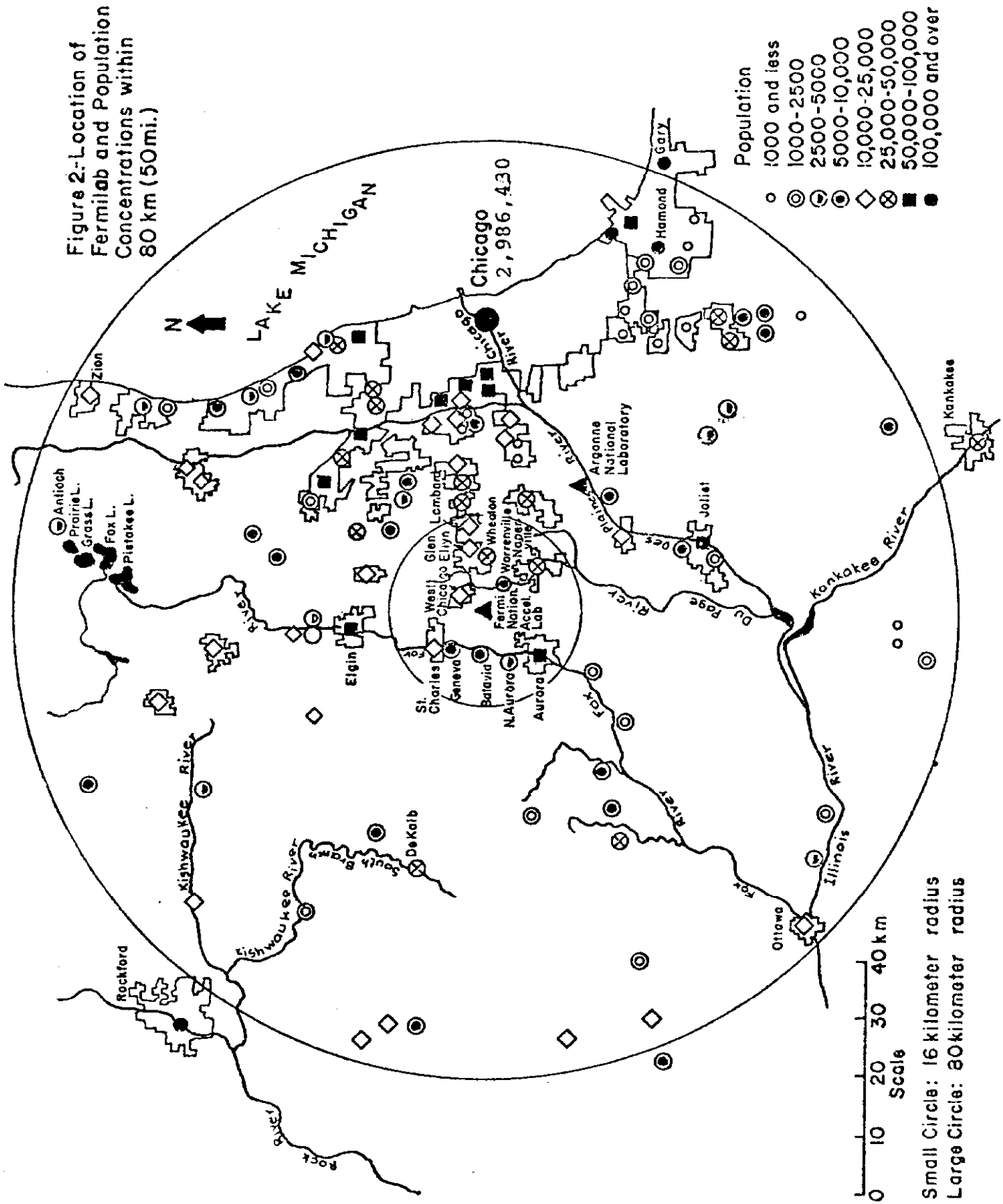
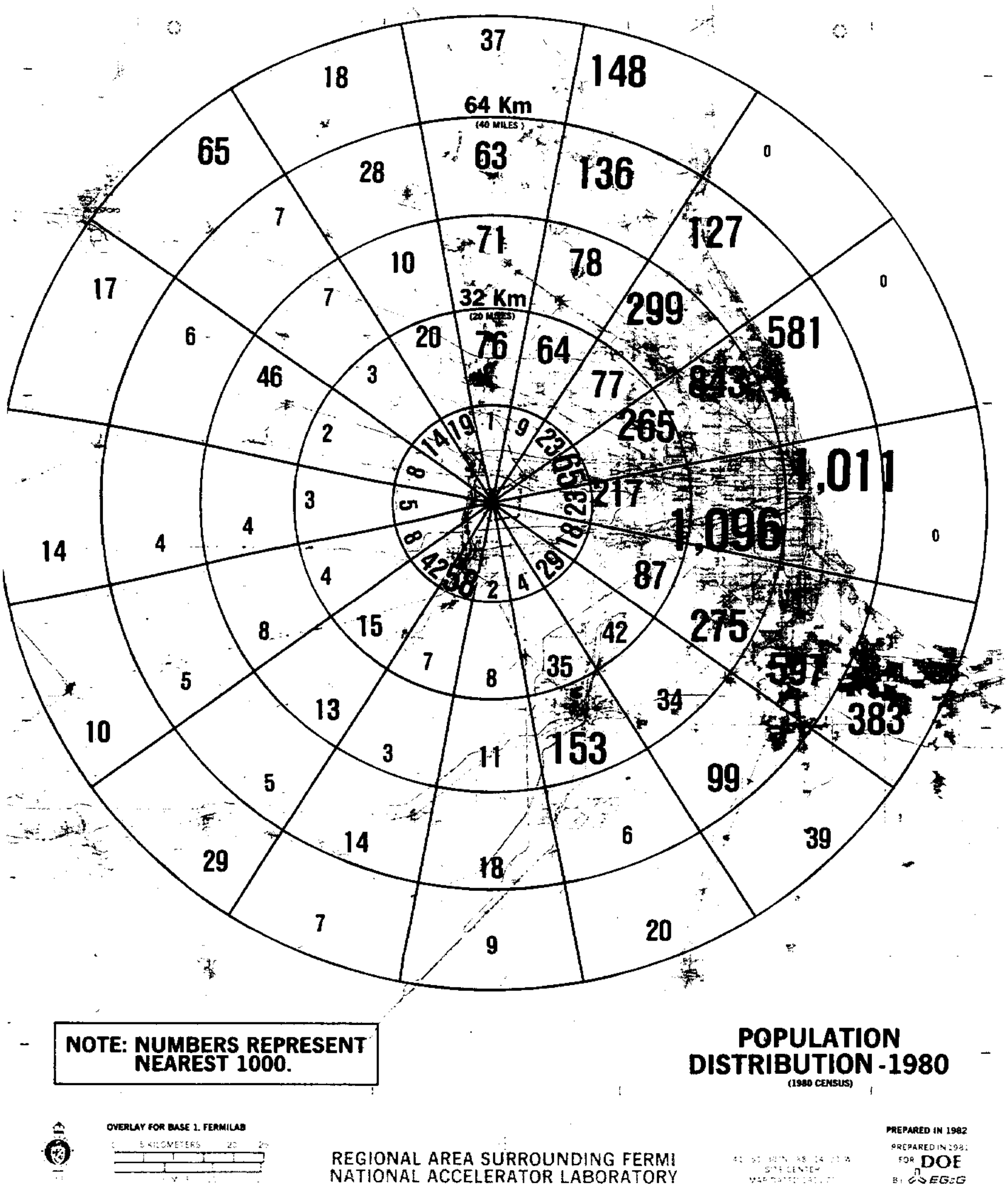


Figure 2-Location of Fermilab and Population Concentrations within 80 km (50mi.)
N
LAKE MICHIGAN
Chicago
2,986,430
Population
1000 and less
1000-2500
2500-5000
5000-10,000
10,000-25,000
25,000-50,000
50,000-100,000
100,000 and over
Zion
Antioch
Prairie L.
Grass L.
Fox L.
Pistakee L.
Rockford
Kishwaukee River
Elgin
St. Charles
Geneva
Batavia
N.Aurora
Aurora
West Chicago
Glen Ellyn
Lombard
Wheaton
Warrenville
Naperville
Fermi National Accel. Lab
DeKalb
South Branch
Fox River
Argonne National Laboratory
Joliet
Des Plaines River
Du Page River
Kankakee River
Kankakee
Hamond
Gary
Ottawa
Illinois River
0 10 20 30 40 km
Scale
Small Circle: 16 kilometer radius
Large Circle: 80kilometer radius

Figure 3

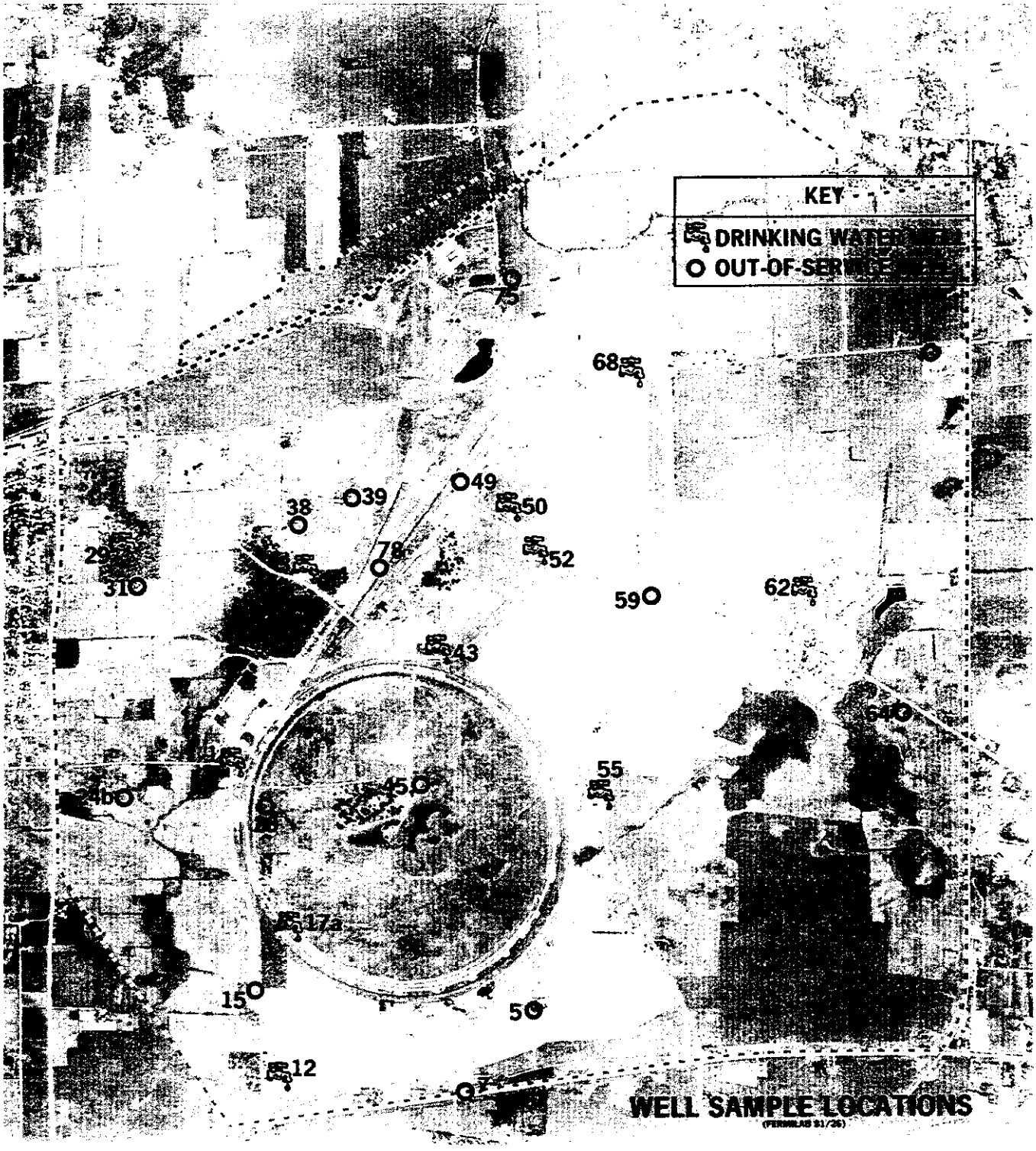

37
148
18
64 Km
(40 MILES)
65
28
63
136
0
7
127
17
10
71
78
7
0
32 Km
(20 MILES)
299
6
20
76
64
581
46
3
77
843
2
14
19
1
9
23
265
8
65
1,011
3
5
23
217
14
4
4
8
18
1,096
0
4
42
58
2
4
29
87
8
15
42
275
5
7
8
35
597
10
13
34
383
3
11
153
5
99
29
14
6
39
18
7
9
20
NOTE: NUMBERS REPRESENT NEAREST 1000.
POPULATION DISTRIBUTION -1980
(1980 CENSUS)
OVERLAY FOR BASE 1, FERMILAB
REGIONAL AREA SURROUNDING FERMI NATIONAL ACCELERATOR LABORATORY
PREPARED IN 1982
FOR DOE
BY EG&G

the DuPage River which passes east of the site flowing south with an average of 265 million liters (70 million gallons) per day through Warrenville (Fig. 2). The rainfall on site during 1984 was 85 cm (33.6 in).[2] The land on the site is relatively flat with the highest area, elevation 244 m (800 ft) above mean sea level (MSL), near the western boundary and the lowest point, elevation 218 m (715 ft), above MSL, toward the southeast. The drainage of the ground water and most of the surface water is toward the southeastern corner of the Laboratory, toward the DuPage River. A somewhat smaller amount drains to the southwest, toward the Fox River. The drinking water in many of the surrounding communities comes from deep wells usually drilled 360 m (1200 ft) deep into the Cambrian/Ordovician aquifer system.[3] Also, there are many individual private wells drilled into the shallow silurian aquifer system around 30 m (100 ft) below the surface.

The drinking water used on the Fermilab site comes from the shallow Silurian dolomite aquifer.[3] These wells (primarily 1, 3, and 62 in Fig. 4) collect water from 20 to 70 m (65 to 220 ft) below the surface. The surface cooling waters are used for cooling the accelerator and some experimental area facilities through heat exchangers. The surface cooling water supply is augmented as necessary by pumping water from the nearby Fox River.

The land within the site boundary was primarily farm land before the State of Illinois acquired the site for Fermilab although the small village of Weston (population around 600 at that time) was located on the eastern

Figure 4


KEY
DRINKING WATER
OUT-OF-SERVICE
75
68
49
39
38
50
52
29
78
31
59
62
43
64
55
45
46
17a
15
5
12
WELL SAMPLE LOCATIONS
(FERMILAB 81/26)
OVERLAY FOR BASE 4, FERMILAB
FERMI NATIONAL
ACCELERATOR LABORATORY
PREPARED IN 1982
DOE

side (Fig. 1). Much of the land, approximately 10 km^2 (2500 acres), has remained in crop production, primarily corn. The village of Weston has provided residences for visiting scientists as well as support facilities for the research program.

2. Summary

The accelerator began an extended shutdown for installation of a superconducting magnet ring in June 1982. Injection of protons into the new accelerator ring began one year later. Extraction of protons to the Experimental Areas occurred in October 1983 and continued until July 17, 1984. The total number of protons accelerated in 1984 was 8.2×10^{17}. This total is approximately 4% of the average of 1.9×10^{19} for conventional magnet operation from 1978 through 1982. Thus, environmental monitoring in CY-1984 was done to investigate the impact of the new superconducting accelerator and to check on effects resulting from previous accelerator operations.

During CY-1984 there were no abnormal occurrences which had an impact on the facility and its operation. In CY-1984 8.3 km^2 (2045 acres) were sprayed with 2,4-D for controlling noxious weeds. In the past as much as 10 km^2 (2500 acres) were sprayed with 2,4-D. This year no 2,4-D was used in residential areas as was necessary last year.[4]

The maximum potential radiation exposure at the site boundary during CY-1984 (fence line assuming 24 hr/day occupancy) was only 0.8 mrem compared to 0.04 mrem last year and to an average exposure of 3 mrem during conventional magnet operations from 1978 to 1982. The dose of 0.8 mrem would correspond to 0.16 percent of the standard of 500 mrem for an individual who is not a radiation worker (Section 5). The maximum individual potential exposure to the general population would be

essentially the same because the decrease in dose rate is small between the site boundary and the location of that individual.

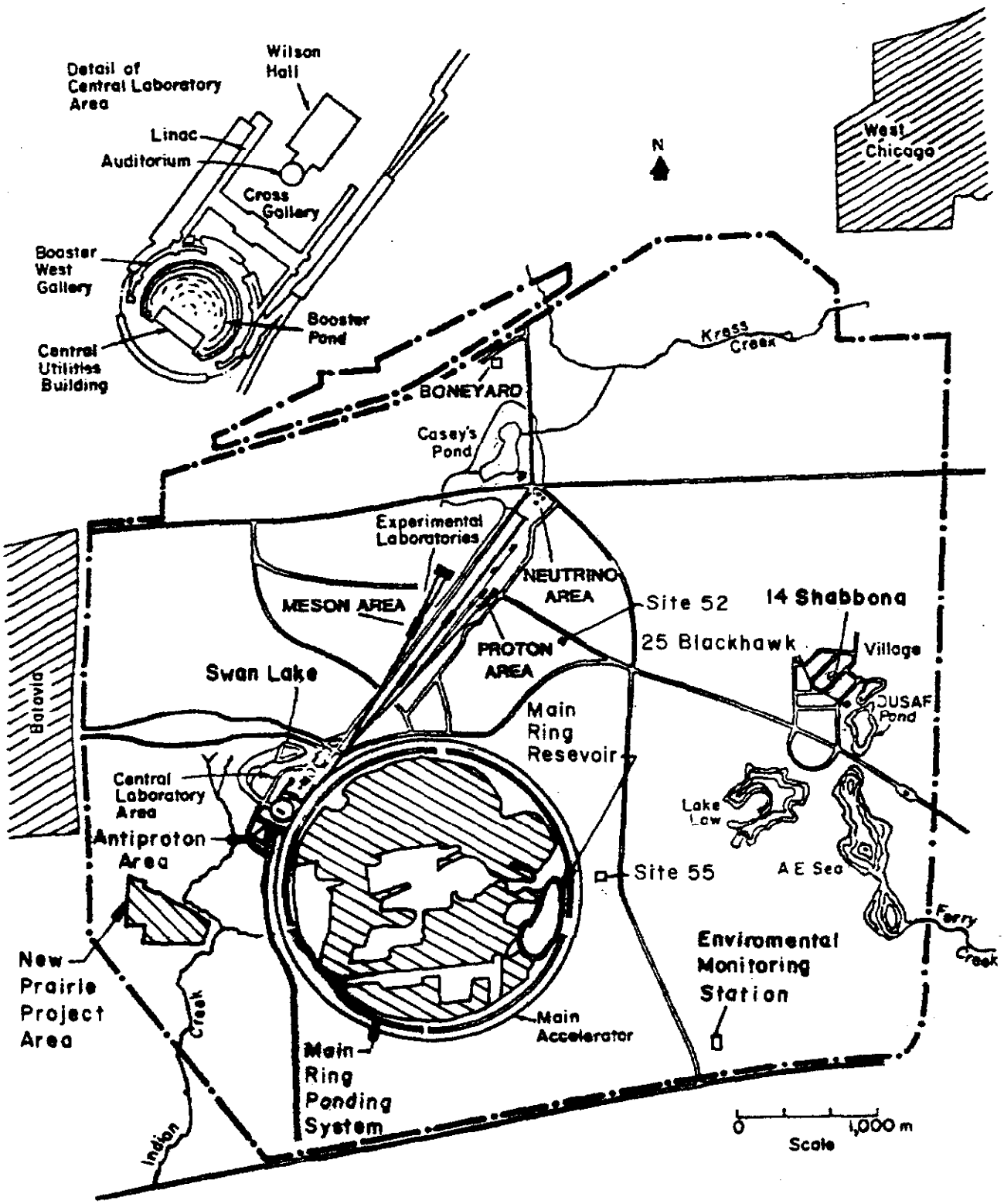
The total potential radiation exposure to the general off-site population from Fermilab operations during CY-1984 was 4.5 person-rem compared to less than 0.1 person-rem last year when the superconducting ring was being commissioned. The primary source of potential exposure was penetrating radiation from muons this year. All exposure was from external radiation, as was the case in the past. Thus, the 50 year dose commitment from operations in 1984 is expected to be the same as the exposure received in 1984.

No airborne radioactivity was released across the site boundary in CY-1984 during accelerator operations because the Neutrino Area primary beam line was not receiving protons. In the past airborne radioactivity was released from the stack ventilating a Neutrino Area enclosure where the proton beam strikes a target. No tritiated water was evaporated as a means of disposal in CY-1984. The off-site release of tritium in surface water totaled approximately 150 mCi, about 23% of last year's release. The primary source of tritium is one sump discharging in the Neutrino Area from an underdrain system beneath the target which has received most of the protons.

The sewage treatment plant, a single-stage oxidation pond, in the Village (Fig. 1) exceeded permit limits for suspended solids in CY-1984. The nine excursions resulted from algae and excessive rainfall on the 0.2

km (5 acre) pond rather than from improperly treated sewage. There was no known adverse environmental impact on the on-site ponds downstream (Fig. 5) or off the site from these nor from the seven occurrences of excess biological oxygen demand, also associated with algae growth. The State of Illinois and the U.S. Environmental Protection Agency were notified of these excursions and have not indicated that there is any problem with compliance. The Illinois Environmental Protection Agency inspected the plant on June 14, 1984 and made no recommendations.

Figure 5. – Fermilab Site



3. Environmental Program Information

Since its inception, Fermilab has endeavored to protect and enhance the environment. For over ten years a prairie restoration project has been in progress on the 1.6 km^2 (400 acre) plot inside the main accelerator ring (Main Ring in Fig. 1). Recently the prairie project was expanded to include an area outside the ring (Fig. 5). Farm houses were moved from their original locations to a site at the south end of the Village (Fig. 1) and renovated to provide housing for scientists performing experiments at Fermilab rather than abandoned and allowed to deteriorate. Some farm wells were maintained for monitoring and others were properly sealed. Ponds and lakes were created to control surface run off and provide cooling water for the accelerator and experimental areas. Over 40,000 trees have been planted to improve the environment. In addition, strong emphasis has been placed on the control of chemical and radioactive environmental pollutants and adequate shielding has been provided for preventing exposure from penetrating radiation.

The Fermilab environmental radiological monitoring program follows, in general, the guidance given in the Department of Energy (DOE) report A Guide for Environmental Radiological Surveillance at DOE Installations.[5] This includes adherence to the standards given in DOE orders, in particular, DOE Order 5480.1A, Chapter XI, which pertains to permissible doses and concentration guides for radioactive releases, and gives guidance on maintaining exposures to as low as reasonably achievable (ALARA).[6] In addition, the environmental monitoring is supplemented by effluent

monitoring following, in general, the guidance given in the Department of Energy (DOE) report A Guide for Effluent Radiological Measurements at DOE Installations.[7]

The emphasis has been placed on potential exposure pathways to workers and the public through the environment which are appropriate to high energy physics laboratories. These pathways include external exposure from direct penetrating radiation and airborne short-lived ^{11}C, and internal exposure from ^{3}H and ^{22}Na in water, primarily potential drinking water. There is one unique characteristic at Fermilab which requires consideration and that is the use of large volumes of sand and gravel in two locations to assist in stopping the high energy protons and secondary particles. Although the ground water beneath these two areas is protected by membranes impervious to water and by underdrain systems to collect the water, radiological monitoring of soil and water is necessary. See Section 3.1.3.4.

Monitoring results are also reported for non-radioactive pollutants. Included as pollutants are pesticides used in weed, insect, rodent, and algae control. In addition, results are included from monitoring the performance of the sewage treatment plant (Village Oxidation Pond) on site. Discharges of suspended solids and measurements of biological oxidation demand in effluent from this plant have sometimes exceeded permit limits. See Section 3.2.4.

3.1 Environmental Radiation Monitoring

The three types of accelerator-produced radiation which receive extensive environmental monitoring are discussed below - penetrating radiation, airborne radioactivity, and waterborne radioactivity. These radiations have direct pathways to the off-site population. Other more indirect pathways, such as through the food chain, have received much less attention to date. The decision on what to monitor is based on the type of operation, radionuclides released, potential hazard, and monitoring results from this and other high energy physics laboratories.

3.1.1 Penetrating Radiation

Operation of the accelerator at current energies and intensities results in production of some penetrating radiation (primarily muons) outside the shielding. Although the shielding has been designed to be adequate for this operation, monitoring for purposes of determining actual radiation levels both on and off the site is necessary.

A large network of detectors was used to monitor penetrating radiation. At the end of CY-1984 there were approximately 120 detectors deployed around the site for the main purpose of protecting on-site personnel. The majority of these detectors were connected to a data logger which automatically recorded the radiation levels for subsequent examination.[8] Because the intensity was low in CY-1984 only four detectors were used primarily for environmental radiation monitoring. One was a

large volume, 110 liter, ionization chamber (called a Hippo) for gamma-ray and charged particle detection. It was located near the Boneyard at the Railhead (Fig. 5). Two of the remaining three detectors were large scintillation counters. The other was a tissue-equivalent ion chamber. One large scintillation counter is located near the site boundary (Environmental Monitoring Station in Fig. 5). The other was located at Site 52 near the experimental laboratories (Fig. 5). The ion chamber is located at 14 Shabbona in the Village (Fig. 5).

The Mobile Environmental Radiation Laboratory (MERL) was used in the past for determining the exposure levels at the site boundary and for locating the source and direction of penetrating radiation such as muons and neutrons.[9,10,11,12] The MERL is a four-wheel-drive vehicle equipped with two 20 cm x 20 cm (8 in x 8 in) scintillation counters, one approximately 15 cm (6 in) behind the other, for muon detection. It also has a dePangher "long counter" for neutron detection.[13]

3.1.1.1 Muons

Measurements of muons from the Proton Area (Proton West and Proton East in Fig. 6) which were made in CY-1980 with 350 GeV protons from the accelerator and in CY-1981 with 400 GeV protons[11] were repeated in CY-1984 with 800 GeV protons.[14] The directions of penetrating muons are shown in Figure 6. The muons which penetrate the earth shielding can travel far beyond the site boundary through the air before stopping. Therefore, measurements were made both on and off the site. The site boundary muon

Figure 6


MESON
NEUTRINO N1 LINE
PROTON WEST
PROTON EAST
PENETRATING RADIATION
UON) DIRECTIONS
(FERMI REPORT TM-1061 1981)
OVERLAY FOR BASE 4, FERMILAB
PREPARED IN 1982
FERMI NATIONAL
ACCELERATOR LABORATORY
DOE

dose rate for CY-1984 was then determined from both the CY-1981 and CY-1984 measurements and the numbers of protons incident on the targets at 400 GeV and 800 GeV since periods of operation at 400 and 800 GeV occurred in CY-1984. The maximum fence line annual dose based on 24 hour per day occupancy was 0.8 mrem for CY-1984 for the Proton Area. Since the dose rate varied inversely with distance and the distance to the nearest off-site individual was small compared to the distance from the muon source, the maximum individual dose rate was approximately the same as the fence line dose in CY-1984.

Based on the CY-1981 and CY-1984 measurements and the numbers of protons sent to the Meson and Neutrino Areas in CY-1984, the fence line doses for CY-1984 were negligible for those areas.

3.1.1.2 Neutrons

Neutrons penetrated the shielding in the most easterly of the external experimental areas (Proton East line in Fig. 5) in the Proton Area in CY-1982.[12,15] However, in CY-1983 additional shielding was added to this area and a different experiment was performed. The result was that a negligible number of neutrons penetrated the shielding in CY-1983 and CY-1984.

3.1.1.3 Gamma Rays

The primary radioactive waste storage area on site - the Boneyard - is also the primary source of off-site gamma radiation. As shown in Fig. 5, the Boneyard, which is a secure area, lies close to the site boundary. On the north side there is an earth berm to prevent any direct radiation from leaving the site. Shielding has been provided above and on all sides of those radioactive materials which would produce high radiation levels without shielding. This was done to protect Fermilab workers as well as reduce the off-site dose. Radiation levels at the site boundary closest to the Boneyard were at background levels in CY-1984.

3.1.2 Airborne Radioactivity

Radioactivation of air in measurable concentrations will occur wherever the proton beam or the spray of secondary particles resulting from its interactions with matter passes through the air. Along most proton beam lines (paths of the protons from the accelerator) the protons travel inside evacuated pipes. Thus, radioactivation of air is now usually caused by secondary particles. Monitoring of such activation is carried out for purposes of personnel exposure control. Under no circumstances is the off-site concentration of airborne radioactivity expected to approach the limits for uncontrolled areas. During CY-1984 the primary target in the Neutrino Area was not in operation. This target has been the source of radioactive gas, primarily ^{11}C, which was produced by interaction of secondary particles from this target with air. Monitoring for ^{11}C

continued even though the primary source was not in operation. No ^{11}C was detected in CY-1984. See Section 3.1.3.3 for vegetation sampling results near airborne release points. Radionuclides are still present from earlier operations.

A debonding oven was placed in operation in CY-1979 in the Industrial Area (Fig. 1). Its purpose is to debond magnets by decomposing the epoxy adhesives at high temperatures. Most of these magnets are radioactive, having failed during accelerator operations. The gaseous effluent was measured during the acceptance test on June 8, 1979 conducted for the Illinois EPA and contained only ^{3}H at very low levels. The test utilized a typical 6 m (20 ft) long magnet reading 0.8 mrem/hr at 0.3 m (1 ft) from the surface and 8 mrem/hr in the bore tube where the protons traveled. The total amount of ^{3}H released from this magnet was 160 μCi at a stack concentration of 1.3×10^{-8} μCi/mℓ or about 20 percent of the Concentration Guide (Section 5) corresponding to 500 mrem per year. The stack is approximately 10 m (30 ft) high. Using the Gaussian plume diffusion model[16] with neutral wind conditions[17] gives a negligible percentage of the applicable Concentration Guide at the site boundary. The number of radioactive magnets debonded in CY-1984 was six corresponding to a total release of 1 mCi of ^{3}H into the air. The radioactivity in the magnets was similar to that in the 1979 test, thus the 1979 data are still valid. In CY-1984 the wind conditions were similar to those in past years. In CY-1984 the average wind speed at O'Hare International Airport, Chicago, Illinois was 4.4 m/sec (9.8 mi/hr).[18] Fermilab is about 43 km (27 mi) from the airport and the terrain between them is relatively flat.

A water evaporator was placed in operation in CY-1981 at the Boneyard (Fig. 4) to dispose of tritiated water collected from closed loop cooling systems. No tritiated water was evaporated in CY-1984.

3.1.3 Waterborne Radioactivity

During accelerator operations, some radioactivation of the soil will occur.[19,20] Leaching of these radionuclides into the ground water provides a possible mechanism for transport of Fermilab-produced radionuclides into the surface run-off waters and aquifer. Hence, a broad program of ground water monitoring for radioactivity is maintained. Measurements are also made of on-site concentrations of radionuclides in Fermilab surface waters and in closed loop (recirculating) cooling systems which are sources of potential off-site releases.

Water samples are collected periodically on site and from surface waters off site. They are analyzed for the presence of those radionuclides which are produced in and leachable from Fermilab soils in measurable quantities.[19] This group of radionuclides also includes those produced in water directly. Analyses are made for ^{3}H, ^{7}Be, ^{22}Na, ^{45}Ca, ^{54}Mn and ^{60}Co. The latter is hardly leachable (approximately 0.1 percent); however, it has been detected in discharges during regeneration of water treatment resin.

Water samples were collected from the following types of wells on site:

1. Farm Wells - Approximately 30 m Deep - 33 Samples

2. Fermilab Water Supplies - Approximately 70 m Deep - 4 Samples plus the quarterly composite samples

3. Fermilab Deep Well Emergency Supply - 436 m Deep - 1 Sample plus a quarterly composite sample

The wells routinely sampled are shown in Figure 4. Water samples were also collected from sumps, creeks, and rivers. All surface and ground water samples collected were analyzed by Teledyne Isotopes, Inc., 1500 Frontage Road, Northbrook, Illinois 60062. Each monthly shipment included at least one sample containing accelerator-produced radionuclides in known amounts to check the accuracy of the assays. See Section 4 on quality assurance.

3.1.3.1 Water Sample Collection

To obtain water samples from wells not in regular use, the wells are pumped for a sufficient length of time to insure that the water standing in the pipe has been pumped out before a sample is taken. The water in the pipe could conceivably have been there since the last time a sample was taken. Normally, the pipe volume is pumped several times before sampling. Water samples from sumps, creeks and other surface waters are normally collected by dipping a bottle well below the surface. Several of the sumps inside normally locked enclosures are sampled by remotely operated peristaltic pumps or the sump pumps themselves. Also, in CY-1984 meters

were added to record the operating time of sump pumps which pumped radioactive water.

The water sampling schedule is based on the following rationale:

1. Wells 38/39*, 43, 49, & 78 are sampled quarterly because they are closest to the areas of maximum soil activation (near targets and dumps) and are in the direction the water would flow in the aquifer.

2. Wells 1, 5, 17A, 20, and 45 are sampled semiannually because they are near the accelerator.

3. The other wells are sampled annually because they are near the site boundary or serve as back-ups to the other wells or as drinking water supplies.

4. The one deep well is sampled annually to look for long-term trends or changes in percolation down to that level.

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*38 and 39 are close to each other and sample the same region of the aquifer. Each is sampled semiannually. See Figure 4.

5. The MF5, N1, N2, and PW8 sumps are sampled bimonthly because they are the closest to the areas of maximum soil activation. See Figure 7.

6. The MF4 sump and the N1 Retention Pit are sampled quarterly because the MF4 sump collects water from a region with less activity than that of the MF5 sump (outside the impervious membrane instead of inside) and the N1 Retention Pit does not have a pump in it even though it collects from a region of higher activity than the N1 sump.

7. The other sumps are sampled less frequently with the frequency based on the tritium concentration found there in the past.

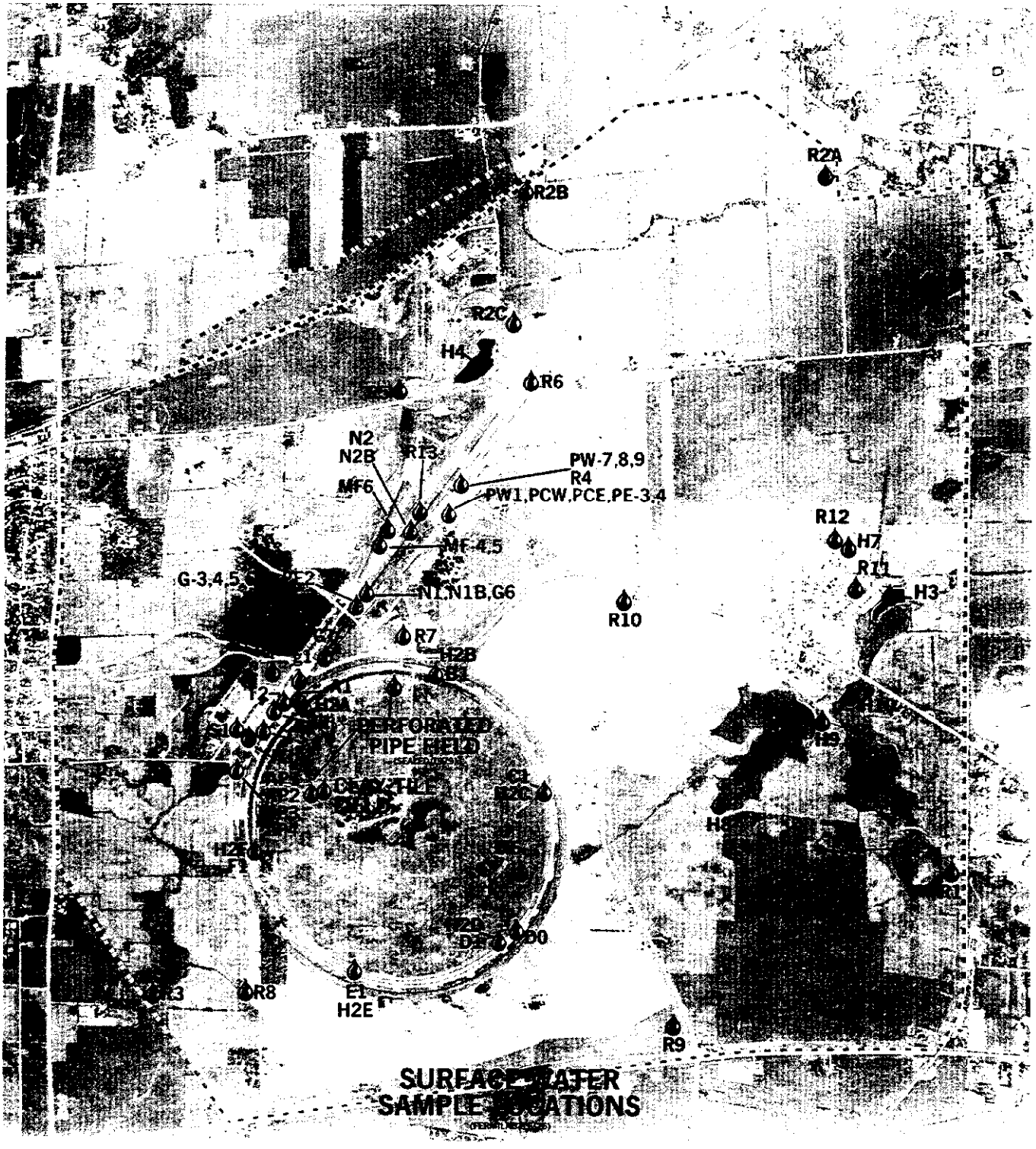
8. The creeks are routinely sampled three times a year and Kress Creek is sampled monthly whenever water from the Laboratory flows over the spillway into the creek. Ferry and Indian Creek sampling was omitted by mistake in CY-1984.

9. Ponds and ditches with a potential for receiving radioactive water are sampled annually.

10. The Fox River and west branch of the DuPage River which receive run-off from Fermilab are sampled annually.

11. The closed loop cooling systems which cool targets and dumps are

Figure 7


R2A
R2B
R2C
H4
R6
N2
N2B
R13
PW-7,8,9
R4
MF6
PW1,PCW,PCE,PE-3,4
R12
H7
MF-4,5
R11
H3
G-3,4,5
N1,N1B,G6
R10
R7
H2B
B1
PERFORATED
PIPE FIELD
C1
H2A
H2
D0
R8
E1
H2E
R9
SURFACE WATER
SAMPLE LOCATIONS
OVERLAY FOR BASE 4, FERMILAB
PREPARED IN 1982
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sampled with a frequency which depends on the level of radioactivity. Operating systems having concentrations greater than 0.01 μCi/mℓ are sampled quarterly (> 333% of the relevant standard in Section 4). Those having concentrations between 0.001 and 0.01 μCi/mℓ (33 and 333% of the standard) are sampled semiannually. Those between 0.00001 and 0.001 μCi/mℓ (0.33 and 33%) are sampled annually.

12. The resin regeneration systems are routinely sampled for analysis by an outside laboratory semiannually. These systems remove radionuclides such as ^{7}Be, ^{54}Mn, and ^{60}Co as well as calcium and other non-radioactive impurities from the resins which keep conductivity of closed loop water systems low. Analyses are performed on site for samples from every regeneration sending radioactive effluent to the Central Utilities Building (CUB) tile field inside the Main Ring.

13. Several samples are collected annually to look for radioactivity leached from steel.

3.1.3.2 Results of Analyses

All current Fermilab water sampling locations for detection of accelerator-produced activity are shown in Figs. 4 and 7. Not all locations need to be sampled every year. See Section 3.1.3.1 above. No accelerator-produced radionuclides were reported in four water samples

taken from Kress Creek (R2A in Fig. 7). The sampling of the other two creeks leaving the site was omitted in CY-1984. No accelerator-produced radionuclides have ever been detected in the creeks. River water samples were obtained once during CY-1984 from the Fox River in Aurora and from the west branch of the DuPage River in Warrenville (Fig. 2). Neither river is utilized as a drinking water supply. No evidence for accelerator-produced radionuclides was found.

The Village water supply (62 in Fig. 4) is the Laboratory's only community water supply. The Main Site water supply does not provide water to residences. Quarterly water samples were collected and a composite analyzed for naturally occurring as well as reactor and accelerator-produced radionuclides in CY-1984. No activity was found using very low detection limits. See Section 4. Although not required, sampling and analyses were also performed for the Main Site supply and the Site 55 supply, Fermilab's other two drinking water systems providing water to more than 25 persons a day. These (1, with 3 as back-up, and 55 in Fig. 4) supply water to Wilson Hall (Fig. 1) and to Site 55 and the east side of the main accelerator (Main Ring in Fig. 1). Initial reports of ^{3}H at the detection level for these samples were shown on reanalysis to be false. Thus, final results were the same as for the Village water supply. The independent testing laboratory Fermilab contracted to analyze water samples in 1984, gave false positive results for several other well water samples in CY-1984. See Section 4 for the quality assurance tests which were used to check the vendor's capabilities.

3.1.3.2.1 Tritium

The results for on-site tritium measurements yielding detectable levels in surface waters (Fig. 7) are given in Table 1. All other sampling points were essentially at background levels. The sumps collect waters from around the footings of the buildings and enclosures. This water is considered surface water. Only aquifers are called ground waters. The total off-site release in surface waters was 150 mCi of tritium this year compared with 658 mCi last year. This decrease represents a reversal in the trend seen in past years in the discharge from the N1 Sump (Figs. 7 and 8). The decrease was due to both a lower tritium concentration and less water flow from the sump and off the site. Only 20% of the discharge from the N1 sump left the site, as discussed below. The release occurred at less than 0.3 percent of the Concentration Guide (Section 5) and made a negligible contribution to the potential off-site dose.

The surface water from the experimental areas flows into Casey's Pond (Fig. 5) except during wet seasons. Then, the pond fills up and barricades are placed at the two entrances to the pond to keep the water from flooding the pump room. When these barriers, called stop logs, are in place, the water bypasses the pond and leaves the site via Kress Creek (Figs. 5 and 9). This was the case for approximately 20% of the year in CY-1984. There was one discharge of less than 1 mCi from a closed loop water system leak into the PW9 Sump in CY-1984. See Table 1. It occurred at a time when water was flowing into Casey's Pond.

TABLE 1

Tritium Detected in On-Site Water Samples

Tritium Concentration C ($\mu Ci/m\ell$)*

Collection Point	Number of Samples Collected	C Max	C Max Error	C Min	C Min Error	C Mean	Percentage of Relevant Standard
G4 Sump	1	6.5×10^{-6}	1.7×10^{-6}	6.5×10^{-6}	1.7×10^{-6}	6.5×10^{-6}	0.2
MF4 Sump	6	1.4×10^{-5}	1.9×10^{-6}	$< 3.0 \times 10^{-6}$	-----	4.2×10^{-6}	0.1
MF5 Sump	6	2.6×10^{-4}	4.9×10^{-6}	$< 3.0 \times 10^{-6}$	-----	1.0×10^{-4}	3.3
N1 Sump	6	2.5×10^{-4}	2.0×10^{-6}	8.1×10^{-6}	0.2×10^{-6}	1.1×10^{-4}	3.5
N2 Sump	5	2.6×10^{-4}	3.0×10^{-6}	3.7×10^{-5}	2.3×10^{-6}	9.4×10^{-5}	3.1
PW8 Sump	4	2.4×10^{-5}	1.7×10^{-6}	1.0×10^{-5}	1.8×10^{-6}	1.8×10^{-5}	0.6
PW9 Sump**	3	2.3×10^{-4}	3.0×10^{-6}	7.9×10^{-6}	1.8×10^{-6}	8.0×10^{-5}	2.6

*C Max is the highest concentration detected in any sample from that location and C Min is the lowest. C Mean is the average for all samples from one location.

**C Max for this sample is high because it was taken following a closed loop water system leak. Typical concentrations are approximately 1×10^{-5} $\mu Ci/m\ell$ for the PW9 Sump.

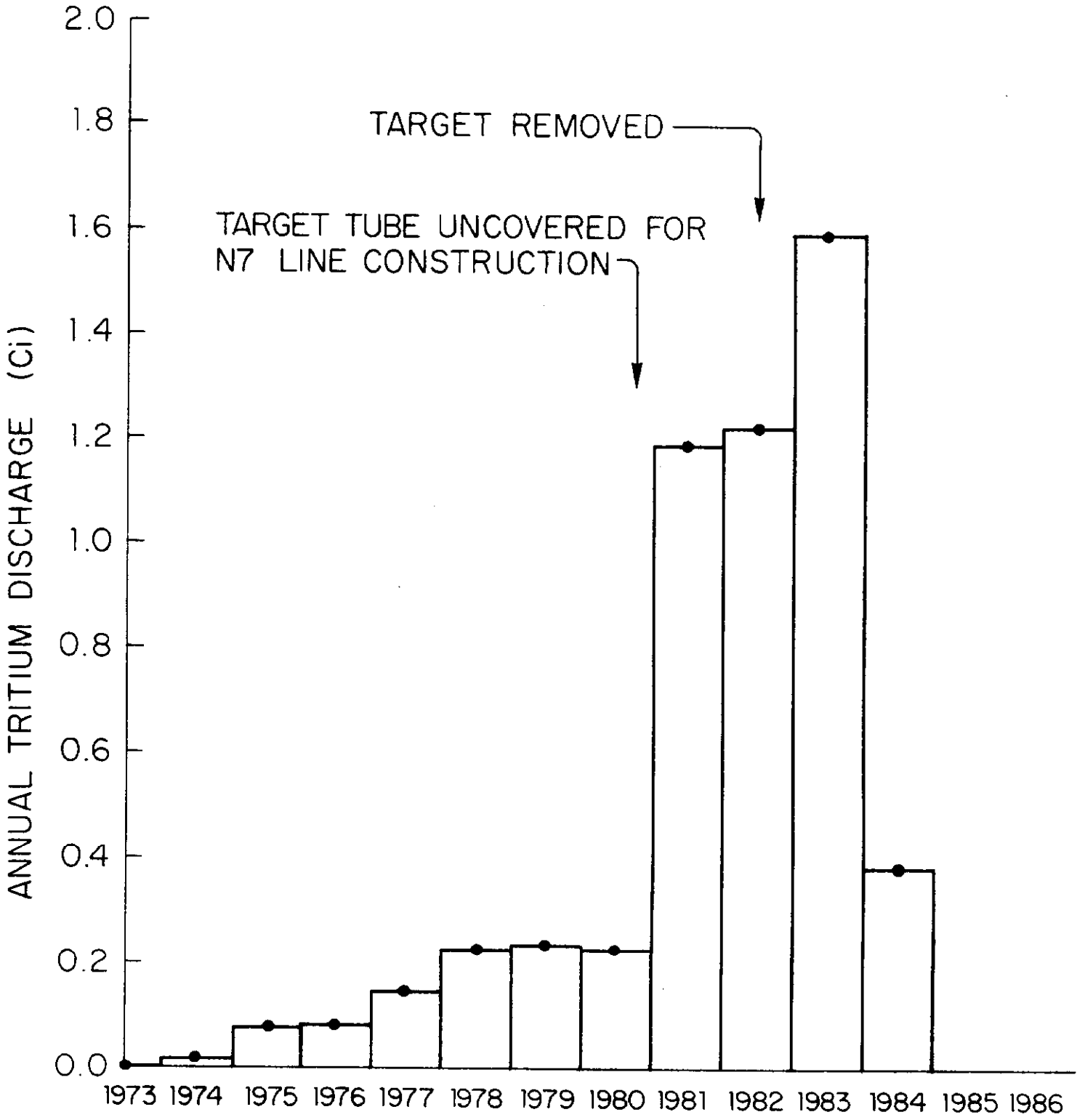
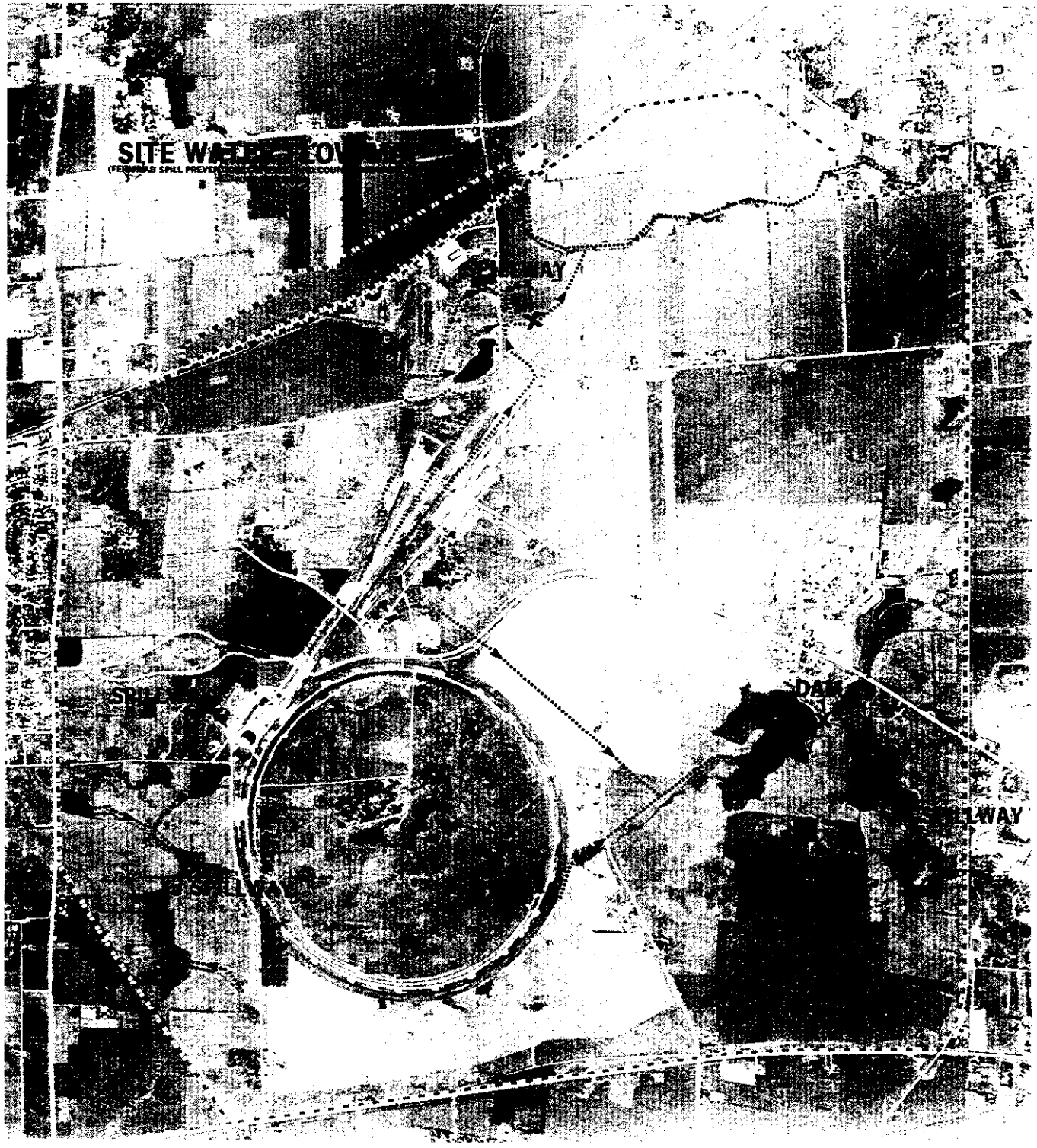


Figure 8. Target Tube Underdrain Discharges

Figure 9


OVERLAY FOR BASE 4. FERMILAB
PREPARED IN 1982
FERMI NATIONAL
ACCELERATOR LABORATORY
DOE

Detailed reports of off-site effluent releases and on-site discharges are made via the Department of Energy Effluent and On-Site Discharge Information Systems, EG&G, Idaho.

3.1.3.2.2 Beryllium

Concurrent with the production of ^{3}H with 12 year half-life is the production of ^{7}Be with 53 day half-life in the closed cooling water systems. The ^{7}Be is chemically active and is easily removed from the water by the resins used to maintain water purity. These resins are regenerated in two separate systems located at the Central Utilities Building (Fig. 5). The effluent from these two systems is sent to a clay tile field inside the main accelerator (Fig. 7). There it percolates into the soil about 60 cm (2 ft) below the surface. The short half-life of ^{7}Be and its strong chemical affinity with the soil ensure that the release will place no burden on the environment. The total amount of ^{7}Be discharged to the tile field in CY-1984 was 27.8 millicuries.

3.1.3.2.3 Other Radionuclides

Tests were also made for radium and thorium in our deep well (4 in Fig. 4) to look for any long-term changes in percolation rates to deep-lying aquifers. The results were consistent showing no changes, as has been the case in the past. Also in CY-1984 tests were made for thorium in the shallow aquifer near the northern boundary of the site to see if any thorium from the surface source in West Chicago was entering the aquifer.[21]

None was found in the samples which were taken from wells W74 and W75 (Fig. 4).

3.1.3.3 Sediment and Vegetation Sampling

Sediment and vegetation samples were taken near discharge points for radioactive effluents. The results for sediment samples are given in Table 2. The vegetation results are given in Table 3. The samples were taken of the top centimeter of sediment in the ditches. Dry weights were obtained by weighing the samples after baking in an oven for approximately 24 hours at 110°C.

TABLE 2

CY-1984 Sediment Sampling Results

Location	Concentration (pCi/g dry weight)			
	^{22}Na	^{54}Mn	^{57}Co	^{60}Co
Ferry Creek	--	--	--	--
Indian Creek	--	--	--	--
Kress Creek	--	0.08±0.03	--	--
A0 Sump Discharge Area	1.41±0.10	0.37±0.04	--	0.08±0.02
D0 Sump Discharge Area	0.59±0.06	0.17±0.03	--	0.09±0.01
MF5 Sump Discharge Area	0.37±0.06	1.29±0.11	0.25±0.04	0.40±0.09
N1 Sump Discharge Area	1.82±0.12	1.08±0.08	--	0.24±0.02
N2 Sump Discharge Area	0.19±0.02	0.17±0.02	--	0.07±0.02
PW8 Sump Discharge Area	--	0.04±0.02	--	--

An annual vegetation sampling program was initiated in CY-1978. Vegetation samples were taken near the ^{11}C exhausts in the Neutrino Area (N1 in Fig. 7) in addition to vegetation samples in areas with waterborne radioactivity. See Table 3.

TABLE 3

CY-1984 Vegetation Sampling Results

Location	Concentration (pCi/g dry weight)				
	^{7}Be	^{22}Na	^{54}Mn	^{57}Co	^{60}Co
Ferry Creek	12±3	--	--	--	0.19±0.13
Indian Creek	10±4	--	--	--	--
Kress Creek	8±4	--	--	--	--
A0 Sump Discharge Area	12±2	0.14±0.04	--	--	0.05±0.01
D0 Sump Discharge Area	4.8±1.7	1.63±0.12	0.37±0.05	--	0.09±0.01
MF5 Sump Discharge Area	13±2	3.44±0.24	12.0±0.7	0.54±0.05	0.95±0.10
N1 Sump Discharge Area	12±3	3.17±0.26	2.03±0.19	--	0.24±0.02
N2 Sump Discharge Area	9.8±2.5	2.29±0.18	--	--	--
PW8 Sump Discharge Area	11±2	0.11±0.06	--	--	--
M1 Stack	9.7±2.4	0.26±0.10	--	--	--
N1 Labyrinth Stack	16±3	0.41±0.10	2.88±0.22	0.24±0.05	0.49±0.16
N1 Spur Stack	16±2	--	--	--	--
CUB Tile Field	28±4	--	--	--	--

The peak concentrations for vegetation sampling are based on the dry weight of the sample. The results from the analyses of the vegetation samples indicated small concentrations of radionuclides similar to those seen in the past.[15] The presence of ^{7}Be in the CUB Tile Field sample is probably from discharges of ^{7}Be in water from resin regeneration. In other samples based on previous results[22] the radionuclide ^{7}Be is expected to be present as surface contamination while other radionuclides are most likely incorporated into the plants. The vegetation contained small quantities of

^{7}Be, even those samples taken adjacent to the creeks near the site boundaries. Since the airborne releases were negligible during this period, the results near the site boundaries are believed spurious, perhaps from cosmic rays, and not related to Fermilab operations. These concentrations and amounts of radioactivity are so low that consumption of the vegetation by animals in the human food chain would be permissible.

3.1.3.4 Soil Activation

Since the percolation rates for water in Fermilab soils are calculated to be very low - less than 1 m (3 ft) per year[23] - analyses of well waters do not provide the early warning desired for detection of accelerator-produced radioactivity in the ground water. To provide such a warning soil samples were taken from the vicinity of targets and other locations where proton interactions result in some radioactivation of the soil. Many radionuclides were detected but since the major long-lived ones leachable from Fermilab soils were ^{3}H and ^{22}Na, quantitative measurements were made only on those.[19]

In CY-1984 a hole was drilled at 45° to sample the soil below the lowest underdrains beneath the Neutrino Area primary target tube (Fig. 10). The target in this 2 m (6 ft) diameter tube has received most of the protons accelerated at Fermilab. The purpose of the hole was to look for radionuclides, primarily ^{3}H and ^{22}Na, which might have been leached and escaped from the water collection system.

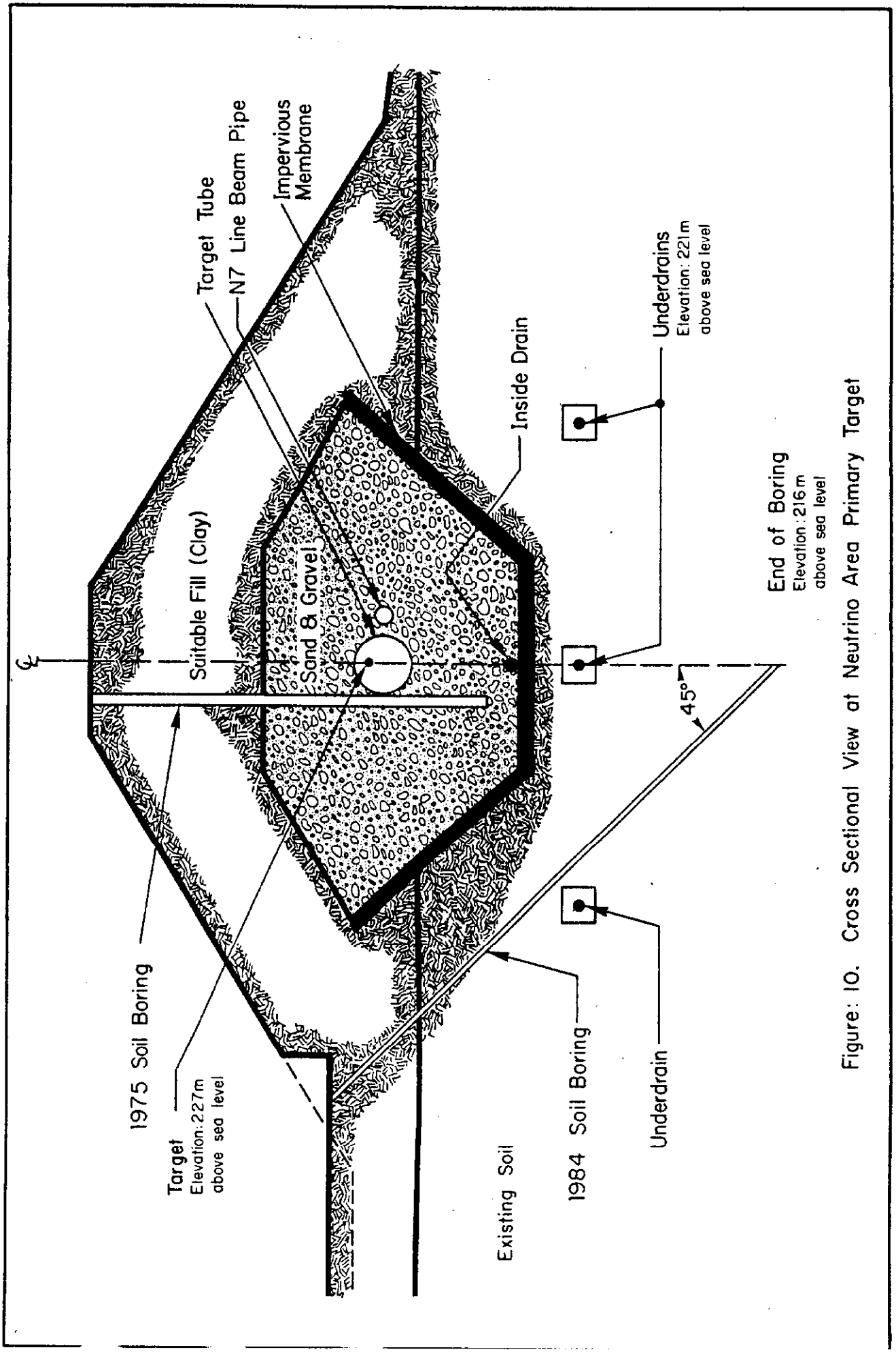


Figure: 10. Cross Sectional View at Neutrino Area Primary Target

The water from the lowest underdrains is discharged into the ditch west of the Neutrino Area (N1 in Fig. 7). The concentration of ^{3}H in this water has remained well below the Concentration Guide for release to surface waters.[6] See Table 1. However, the quantity discharged annually increased significantly in CY-1981 (Fig. 8) shortly after the target area was excavated to install an adjacent pipe for a new beam line (N7 Line in Fig. 10).[24] The target was removed in late CY-1982 and installed in a new location constructed with a protective membrane approximately 120 m (400 ft) away (south). Therefore, the current inventory of radionuclides around the target tube is expected to decrease by radioactive decay in the future.

The concentrations of ^{3}H found in the sample removed from the 45° hole at the elevation of the lowest underdrain was (10.8±0.4) pCi/mℓ where the volume is expressed in milliliters of water present in the soil sample (moisture content). The concentration of ^{3}H in the sample from the bottom of the hole 5.5 m (18 ft) below the lowest underdrain was less than 1 pCi/mℓ. The concentrations of ^{22}Na at the higher and lower elevations were (0.056±0.031) and (0.016±0.035) pCi/g, respectively. Thus, the underdrains are collecting the radioactive water and no evidence was found for large quantities of radionuclides headed for the aquifer.

3.2 Environmental Monitoring for Non-radioactive Pollutants

3.2.1 Domestic Water Supplies

The domestic water supply at Fermilab is essentially provided by two wells pumping from an aquifer approximately 70 m (220 ft) deep. One (1 in Fig. 4) is located in the Central Laboratory Area and the other (62 in Fig. 4) supplies the separate Village system. A third well (3 in Fig. 4) pumps from the same aquifer and supplies water to the Main Site System when demand exceeds the capacity of the Central Laboratory well (1 in Fig. 4).

These wells have chlorination systems and our water laboratory conducts tests for pH and fecal coliform monthly. The chlorine level in the chlorinated drinking water supplies is tested each work day. Test results conformed to Illinois standards during 1984. Samples of the Main Site (Central Laboratory Area) and Village Supplies are independently analyzed by the Illinois Environmental Protection Agency quarterly for total coliform per 100 mℓ. No coliform was found. Our average use from these wells was approximately 328,000 ℓ/day (87,000 gal/day), an increase of 9% from 1983.[4]

Wells are monitored biennially to determine compliance with State of Illinois regulations for non-radioactive pollutants such as heavy metals.[25] Eleven drinking water wells* (Fig. 4) and two wells (20 and 45 in Fig. 4) near the CUB Tile Field (Fig. 5) were sampled directly in CY-1983.[4] Also, samples were taken from the distribution systems of three of the 13. The water was analyzed for 12 metals including arsenic, chronium, iron, lead, mercury, and zinc. Total dissolved solids, chloride, fluoride, sulfate, and nitrate plus nitrite were also measured as well as pH and cyanide. The analyses were performed by Environmental Research Group, Inc., Bridgeview, Illinois 60455. No sampling was done in CY-1984 for these pollutants.

3.2.2 Industrial Water Ponding Systems

There are several water systems used for cooling magnets and for fire protection:

The Industrial Cooling Water (ICW) System consists of Casey's Pond (Fig. 5) at the end of the Neutrino Beam Line and underground mains to fire hydrants and sprinkler systems throughout the Central Laboratory Area and Experimental Areas. Casey's Pond is supplied by surface drainage and can also be supplied by pumping from the Fox River. The pond holds 68,000,000 ℓ (18,000,000 gal).

*Wells 56 and 58 south of 55 in Fig. 4 were substituted for Wells 12 and 43 which are not being used for drinking water at the present time.

The Swan Lake/Booster Pond System (Fig. 5) is used for cooling purposes at the Central Utilities Building (CUB). Water is pumped from the Booster Pond into a ditch in which it runs by way of a small West Pond into Swan Lake. The water is then returned to the Booster Pond by a return ditch. Water is also pumped from Swan Lake to NS1 Service Building (N1 in Fig. 7) for cooling purposes, from which it returns by a surface ditch. This system can be supplied water from the ICW System and it overflows into Indian Creek (Figs. 5 and 9).

The Main Ring Ponding System consists of a series of interconnecting canals completely encircling the interior of the Main Ring with a large reservoir pond inside the Main Ring Ponding System (Fig. 5). This water is used in heat exchangers at the Service Buildings for cooling the Main Ring magnets. The system is generally supplied by surface drainage, although make-up water can be pumped from Casey's Pond. The system overflows into Lake Law (Figs. 5 and 9). The public is excluded from the area inside the Main Ring, and hence the Main Ring Ponding System, when the accelerator is in operation. The water in these systems normally meets the quality requirements of water in general use in Illinois (Section 5).

3.2.3 Other Lakes and Ponds

Surface drainage from the eastern portion of the site flows into Lake Law, DUSAF Pond and the AE Sea (Figs. 5 and 9). The chlorinated effluent from the Village sewage treatment plant oxidation pond (just north of DUSAF Pond) also flows into DUSAF Pond. These lakes and ponds are accessible to the public, and they are the head waters of Ferry Creek.

Semi-annual tests are made of water samples taken where the three creeks leave the site (R1, R2A, and R3 in Fig. 7), as well as from Casey's Pond and the Fox River. Results for 1984 are found in Table 4. Tests for fecal coliform bacteria are made monthly in our water laboratory. The high reading for the Indian Creek sample in September was followed up by taking more samples farther upstream on the site. Swan Lake (Fig. 5) met the standard. Construction of the new Antiproton Source just south of the Central Laboratory Area (Fig. 5) is believed to be the origin for the problem. Run-off from this area flows into Indian Creek carrying nutrients and organisms from disturbance of the environment in the construction area. Construction will be completed in CY-1985.

3.2.4 Sewage Treatment

An authorization permit to discharge under the National Pollutant Discharge Elimination System (NPDES) was obtained for the Village Oxidation Pond (just north of DUSAF Pond in Fig. 5) in 1979.[26] An application to renew this permit has been submitted to the Illinois Environmental Protection Agency. Monthly testing results for 1984 are in Table 5.

The Main Site sewer system was connected to the City of Batavia system June 26, 1979 and has been delivering sewage to the Batavia sewage treatment plant since that time.

TABLE 4

Site Wide Water Quality Report for CY-1984

	pH		DO mg/ℓ		BOD5 mg/ℓ		Susp. Solids mg/ℓ		Fecal Coliform mg/ℓ	
	April	Sept.	April	Sept.	April	Sept.	April	Sept.	April	Sept.
Ferry Creek	8.3	7.8	8.5	6.4	7.1	7.8	48	66	0	4
Kress Creek	7.8	7.9	8.6	8.3	8.2	2.7	6	109	0	104
Indian Creek	7.8	7.6	8.6	7.0	0.8	7.2	1	32	0	**
Casey's Pond	8.0	8.5	8.6	9.5	3.2	5.4	26	13	0	18
Fox River	8.4	8.3	8.9	7.0	6.1	2.9	34	33	0	148
General Standards[21]	6.9 - 9.0		Not less than 5.0 at any time		*		*		Mean of 200	

*There are standards for effluent from treatment works or waste water sources, but no general standards.

**Too numerous to count individually.

TABLE 5

Village Sewage Treatment Plant

Monthly Averages Report for CY-1984

Parameter	Permit Limit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
pH	6-9	7.3	7.2	8.8	8.5	7.9	7.4	8.2	8.3	8.3	8.2	7.8	8.0
BOD5 mg/ℓ	10	4.9	4.9	16.4*	14.8*	8.0	5.4	9.6	11.6*	20.0*	21.2*	22.4*	14.4*
Suspended Solids mg/ℓ	12	8	6	38*	29.5*	6.8	18.5*	16.5*	20.0*	36.5*	25.5*	37.5*	22.5*
Fecal Col. #/100 mℓ	400	0	0	0	0	0	0	0	0	0	0	0	0

*Violation Report filed

The NPDES permit for the Village sewer system granted in 1979 has limits for 30 days average BOD5 and suspended solids of 10 mg/ℓ and 12 mg/ℓ, respectively. The Village system exceeded the limit for suspended solids nine times in CY-1984, in spite of treatments with Aquazine to control algae. The limit for BOD5 was exceeded seven times. See Table 5. These results are reported to the U. S. Environmental Protection Agency quarterly and to the Illinois Environmental Protection Agency semiannually.

3.2.5 Chemical Treatment of Water Systems

Some chemical treatment of our various water systems is required each year to control the growth of algae and aquatic weeds. Only EPA registered agents are administered by trained personnel following the manufacturer's directions.

3.2.5.1 Dalapon

Dalapon was used to treat drainage ditches for control of common cattail (Typha latifolia) growth. Applications were made to ditches in the external experimental areas and along the Main Ring Road inside the main accelerator. A total 329 kg (725 lb) was applied to an estimated 34 km (21 mi) of drainage ditches.

3.2.5.2 Chlorine

In addition to the routine chlorination of the domestic water systems, the swimming pool and the Village Oxidation Pond, a chlorination system for the Swan Lake cooling pond system has proved successful in helping to eliminate the need for chromate treatment of the cooling towers. Chlorine is added to the cooling water for a period of 30 minutes four times a day at a rate which results in a chlorine concentration of 0.5 ppm as the cooling water leaves the equipment.

3.2.5.3 Aquazine

As previously mentioned, it was necessary to treat the Village Oxidation Pond to control algae growth and reduce suspended solids. The pond was treated twice in CY-1984, following the manufacturer's application instructions. The total quantity of Aquazine used was 136 kg (300 lbs).

Aquazine was also used to treat the Main Ring Ponding System and the Swan Lake/Booster Pond System in CY-1984. Approximately 540 kg (1200 lbs) of Aquazine was applied to the Main Ring Ponding System and 39 kg (85 lbs) was applied to the Swan Lake/Booster Pond System.

3.2.5.4 Heavy Metals and Other Toxic Materials

The continued success of the Swan Lake cooling pond system again made it possible to eliminate the use of chromates in 1984. Although it was necessary to use the cooling towers during the warm summer months, it was not necessary to treat the towers with chromate compounds. The chlorinated Swan Lake cooling pond water was passed through the cooling system and a biodispersant, Nalco 7348, was added which lifted deposits from the metal surfaces so they could be oxidized by the chlorine. The rate of application was 3.6 kg (8 lbs) per day with a peak concentration of 20 mg/ℓ. Nalco 7348 is a polyglycol manufactured by Nalco Chemical Company, 2901 Butterfield Road, Oak Brook, Illinois 60521. Another Nalco product, Nalco 7387, was applied continuously to maintain less than 1 mg/ℓ with a peak total phosphorus concentration of 1.3 mg/ℓ. The rate of application was the same per day as for Nalco 7348. Nalco 7387 is an organophosphorus compound which prevents scale formation. It does not have the toxic properties of organic phosphorus esters found in some restricted-use pesticides.[27]

Two closed-loop water systems containing ethylene glycol leaked in CY-1984. Both were in the Experimental Areas. One at the NS-2 Service Building (N2 in Fig. 7) discharged approximately 1500 ℓ (400 gal) of ethylene glycol into the environment. The other at the NS-4 Service Building 300 m (1000 ft) to the north lost approximately 6800 ℓ (1800 gal) of ethylene glycol. Ethylene glycol is biodegradable in contact with soil; however, products found below the surface were black with a strong odor.

Exposure to air and sunlight eliminated the problem. Also, the systems which leaked have been repaired. The underground line near the NS-4 Service Building has been replaced.

3.3 Environmental Permits

As mentioned in Section 3.2.4 Fermilab has a NPDES permit (IL0025941) for discharge of sewage from the Village Oxidation Pond. The State of Illinois and the U.S. Environmental Protection Agency were notified of all permit violations in CY-1984 and have not indicated that these excursions require actions. The noncompliance of the pond with the low limit for suspended solids has been discussed in a meeting with the Illinois Environmental Protection Agency.[28] Algae are the primary constituents of the suspended solids rather than improperly treated sewage. The noncompliance has had negligible environmental impact on the on-site ponds (Fig. 5) or off the site. The Illinois Environmental Protection Agency inspected the Village Oxidation Pond on June 14, 1984 and found it satisfactory. No recommendations were made.

The magnet debonding oven (Section 3.1.2) has an Illinois Environmental Protection Agency permit (I.D. No. 089801AAD D/O-1) which expires May 7, 1989. There have been no cases of noncompliance.

Fermilab has an interim permit (USEPA I.D. No. IL6890030046) to operate a hazardous waste storage facility. This permit was issued by the U.S. Environmental Protection Agency and will expire November 1, 1988. The facility is in compliance with regulations.

EMCO Wheaton coaxial vapor recovery systems have been installed on all gasoline dispensing equipment at Fermilab. This was done in 1980 under a permit (Application No. FG523) issued by the Illinois Environmental Protection Agency. The permit expires July 22, 1985. There have been no compliance problems with the systems.

Fermilab has a permit for open burning for the purpose of training fire department personnel. This permit was issued by the Illinois Environmental Protection Agency (I.D. No. 043807) and expires on August 27, 1985. In addition, Fermilab conducts an annual burning of the prairie restoration areas.

3.4 Assessments and Impact Statements

No formal environmental assessments and no environmental impact statements were prepared in either draft or final form during the year at Fermilab. However, there is an on-going program in place to routinely evaluate new projects and modifications to existing operations and facilities to determine if there is a significant potential for impact. Also, see Section 3.7 for the evaluation of operations conducted in CY-1984.

3.5 Summary of Significant Environmental Activities

In the early 1970's Fermilab began a prairie restoration project on the approximately 1.6 km^2 (400 acre) plot inside the main accelerator (Fig. 4). Three endangered species of prairie plants (Cypripedium Candidum, Iliamna remota, and Petalosteum foliosum) and one threatened plant (Filipendula rubra) have been introduced into the plot. Also, in CY-1984 some Fermilab land (0.11 km^2 or 28 acres) outside this plot has been plowed and seeded with prairie plants (Fig. 5). There are very few remanents of the original Illinois prairie left. The Fermilab restoration is one of the largest prairie sites in the country. The harvesting of seeds is done by volunteers and the environmental aspects receive the attention of a prairie committee consisting of laboratory personnel and outside university representatives.

In late CY-1984 a new building was constructed for storing hazardous waste. It will be the first heated building at the Hazardous Waste Storage Facility (Site 55 in Fig. 5). This will permit indoor storage of wastes which freeze and, in some cases in the past, have ruptured drums. It will also permit drum storage of volatile solvents and gases which overpressure in the hot summer sun. Finally, it will have a hood for processing small quantities of special chemicals.

In CY-1984 a new process for etching copper from printed circuit boards was introduced at the Printed Circuit Laboratory in the Village (25 Blackhawk in Fig. 5). This system uses ferric chloride which is recycled

off the site. The previously used process used ammonium persulfate which had to be sent to an approved disposal facility for burial. The effluent released from the new system has been tested and meets the requirements for discharge into waters in general use at the point of discharge into the Village Oxidation Pond.[25]

3.6 Summary of Hydrogeology

The Fermilab site has thick glacial till consisting primarily of low permeability clay.[29] This clay forms a barrier to the downward percolation of any water containing radioactivity. Beneath the clay the first layer of rock is a dolomite of Silurian age.[3] Its fractured upper 3 m (10 ft) carries sufficient water for individual farm needs. The water level contours for this aquifer are shown in Fig. 11. Note that the water from the Experimental Areas flows toward Well 1, the primary on-site drinking water supply (Fig. 4). Groundwater leaves the site and flows southwest toward the Fox River and southeast toward the West Branch of the DuPage River.

Beneath the silurian dolomite are older formations laid down by sedimentation during the Cambrian and Ordovician periods when the region was under sea water. These consist of dolomite and sandstone with perhaps some shale. The sandstone aquifer at approximately 400 m (1333 ft) below the surface provides sufficient volumes of water for municipal water supplies.

Figure 11


GROUND WATER
LEVEL CONTOURS
AND PRELIMINARY MAP #2
NOTE: CONTOUR INTERVALS IN FEET
ABOVE SEA LEVEL
712
710
708
706
704
702
700
698
696
694
OVERLAY FOR BASE 4, FERMILAB
PREPARED IN 1982
FERMI NATIONAL
ACCELERATOR LABORATORY

The spillways should be noted as shown on the map of surface water drainage (Fig. 9). In the event of an accidental spill, backup efforts will be concentrated at those points to stop the flow of any hazardous substance if it cannot be contained closer to the discharge point.

3.7 Evaluation of Environmental Impacts

3.7.1 Assessments of Potential Radiation Dose to the Public

Fermi National Accelerator Laboratory is located in the densely populated Chicago Area. There are about eight million people living within 80 km (50 mi) of the site (Fig. 3).[30] There are 326,645 people within 16 km (10 mi) of the center of the main accelerator based on the 1980 census results compared to 265,677 counted in the 1970 census. The detailed distribution of population as a function of distance and direction from Fermilab is given in Table 6.[30] The population distribution close to Fermilab is shown in Figure 12.

The dose rate at the site boundary from Fermilab operations was primarily from muons. Earlier measurements of muons showed they went in one direction (toward the northeast). The maximum annual dose rate at the site boundary and the annual dose to the off-site individual receiving the maximum dose from Fermilab operations are essentially the same since the change in distance is small to the site boundary to off-site housing compared to the change in dose rate with distance. The total dose to the individual is 0.8 mrem for CY-1984. The point where that exposure occurred is along the path muons traveled which originated in the Proton Area. This

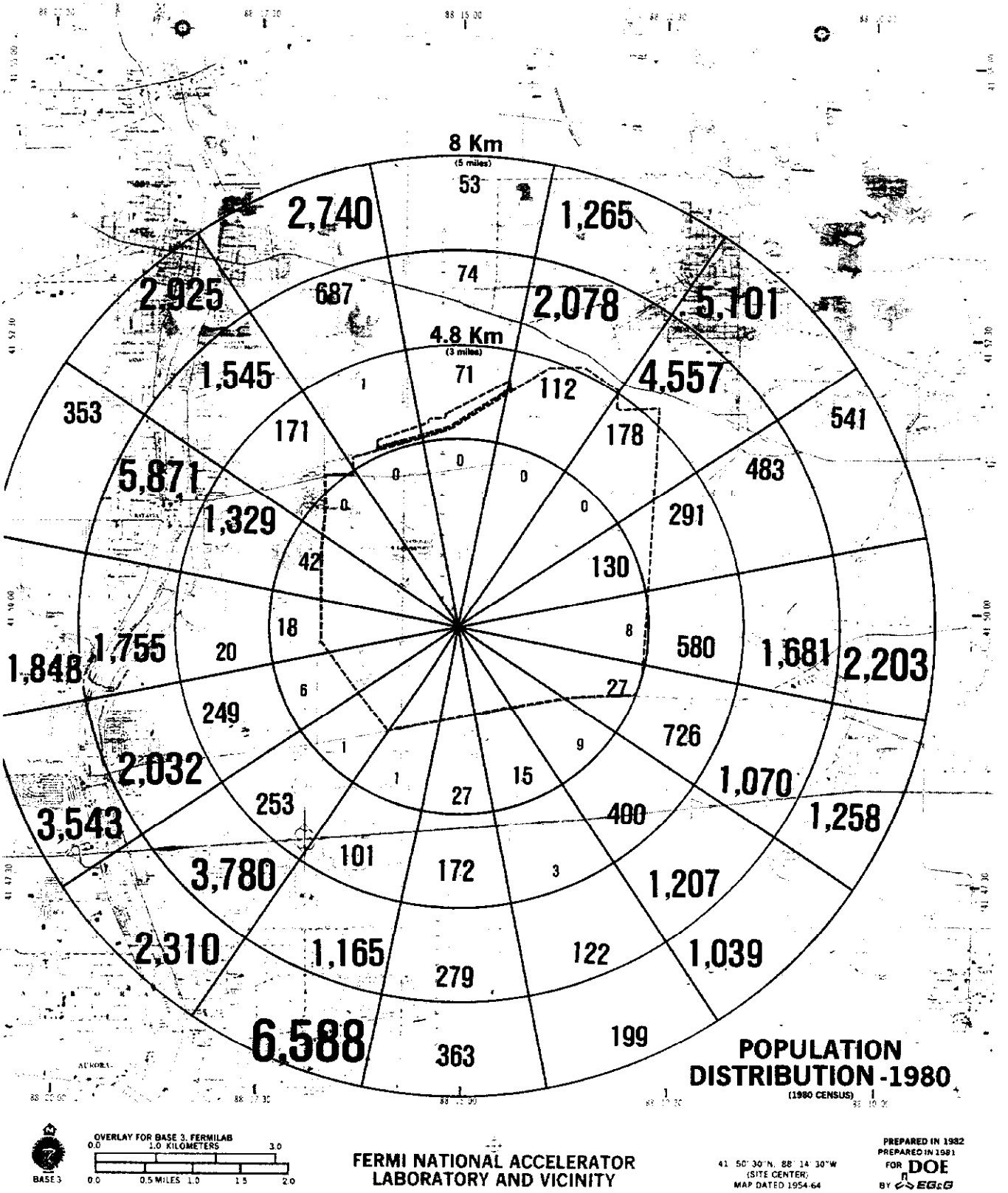
TABLE 6

Incremental Population Data in Vicinity of Fermilab, 1980

DISTANCE, KILOMETERS FROM CENTER OF MAIN RING	0-8	8-16	16-32	32-48	48-64	64-80	80-97	97-113	113-128
DISTANCE, MILES	0-5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80
DIRECTION									
N	198	1110	77247	75658	63188	37183	30696	28459	149892
NNE	3455	5821	68274	76075	120930	145415	100858	173092	87495
NE	9836	12718	78701	292724	139718	0	0	0	0
ENE	1445	63784	263526	840460	551913	0	0	0	0
E	4472	18423	218631	1107254	924752	0	0	33317	56442
ESE	3081	15075	92242	268040	597113	379986	196888	78056	17600
SE	2655	25167	37956	34405	106938	38944	24651	11963	10027
SSE	339	3262	44203	148699	7962	21154	70503	10828	13195
S	841	1336	8604	10301	17011	11089	6640	4354	11967
SSW	7055	49656	8635	3492	17420	6373	25217	24588	10469
SW	6344	35851	13598	15566	5317	30917	36362	13671	13226
WSW	5030	2205	5578	6322	4509	10930	8474	11704	12175
W	3641	971	2941	5339	5111	13693	8445	28768	49103
WNW	7595	851	3018	42762	6723	21231	40449	13891	37012
NW	4641	9607	3297	7974	7358	65288	157549	71682	28229
NNW	3428	15152	22722	10674	29830	17952	29399	24276	58430
TOTAL	65656	260989	949171	2945745	2605793	800155	736131	528649	555262
CUMULATIVE TOTAL	65656	326645	1275816	4221561	6827354	7627509	8363640	8892289	9447551

LATITUDE = 41.832 LONGITUDE = 88.251

Figure 12


8 Km
(5 miles)
4.8 Km
(3 miles)
53
74
71
112
2,740
1,265
2,925
687
2,078
5,101
1,545
4,557
353
171
178
541
5,871
483
1,329
291
42
130
18
8
1,848
1,755
20
580
1,681
2,203
6
27
249
726
2,032
1
9
1
15
1,070
27
253
400
1,258
3,543
101
172
3
3,780
1,207
2,310
1,165
122
1,039
279
6,588
363
199
POPULATION
DISTRICTION -1980
(1980 CENSUS)
OVERLAY FOR BASE 3, FERMILAB
0.0 1.0 KILOMETERS 3.0
0.0 0.5 MILES 1.0 1.5 2.0
BASE 3
FERMI NATIONAL ACCELERATOR
LABORATORY AND VICINITY
41° 50' 30" N, 88° 14' 30" W
(SITE CENTER)
MAP DATED 1954-64
PREPARED IN 1982
PREPARED IN 1981
FOR DOE
BY EG&G

is approximately 0.6 percent of the background radiation dose.[31]

The radiation exposure to the general population from operation of Fermilab in CY-1984 was 4.5 person-rem. This exposure was from muons. This is to be compared with a total of approximately one million person-rem to the population within 80 km (50 mi) from natural background radioactivity.[30,31] Radiation from diagnostic x-rays, medical treatments, and other artificial sources accounted for about 500,000 person-rem in CY-1984.[31]

The exposure from muons was determined by starting with the dose to the maximum individual near the site boundary and calculating dose versus distance from the point on site where the penetrating radiation (Section 3.1.1) originated to 80 km (50 mi) from the site using the inverse square of the distance and summing over the appropriate numbers of individuals. The dose was received by individuals living only in a portion of the northeast sector. See Table 7.

The magnet debonding oven was used to debond only six radioactive magnets in CY-1984. The resulting ^{3}H release from the debonding oven stack had negligible impact.

TABLE 7

Summary of Population Exposures for CY-1984
Within an 80 km (50 mi) Radius of Fermilab

Source	Contributions to Population Exposures (person-rem)
Penetrating Radiation from Proton Area	4.5
Penetrating Radiation from Meson and Neutrino Areas	0.0
Airborne Radioactivity from All Areas	0.0
TOTAL	4.5

Several of the closed loop cooling systems were drained during the extended shutdown in CY-1982-3. These were at levels where potential off-site releases, from these loops, would be detectable but not hazardous. The tritiated water was evaporated.[4] One release of less than 1 mCi occurred from one of these closed loop systems in CY-1984. Some releases of radioactive water occurred from sumps collecting water from under areas where protons interacted. About 20% of this volume of water left the site while Casey's Pond (Fig. 4), the reservoir receiving water from discharges in the three external areas to which protons are delivered, was full. The mean concentration of tritium during the period of release was less than one percent of the Concentration Guide for uncontrolled areas. Also, drinking water in the area is taken from wells rather than from the creek receiving the discharge. Hence, the dose from the release is negligible.

The D0 abort system was replaced by a new abort system at C0 in CY-1983, featuring a well-shielded dump (at C1 in Fig. 7). Therefore, no additional soil activation is expected near D0 in the future. The soil was sampled near D0 in CY-1983.[4] Based on those sampling results, no environmental impact is expected from the D0 abort system. The soil activation associated with the new system at C0 should be much lower than at D0.

A 45) hole was drilled and the soil was sampled beneath the primary target in the Neutrino Area. No evidence was found for movement of radionuclides toward the aquifer (Section 3.1.3.4).

3.7.2 Assessment of Non-radioactive Pollutant Releases

Although it was necessary to chemically treat some waters to control the growth of algae and weeds during CY-1984, efforts were made to keep these treatments as low as possible in order to protect wildlife and fish. The chemicals used - aquazine and dalapon - are biodegradable and no environmental impact was detected.

There were no activities during CY-1984 which created problems with respect to non-radioactive airborne effluents. Heating is accomplished by use of natural gas, liquefied propane gas, or electricity. The bulk of the heating is supplied by natural gas fired boilers located in the Central

Utilities Building. The effluents from these boilers are analyzed annually to maintain proper combustion efficiency.

3.7.3 Potential Impact of Other Toxic Substances

3.7.3.1 Pesticides

In addition to the water treatments mentioned in Section 3.4.3, the following EPA registered herbicides, insecticides and rodenticides were applied by trained personnel following the manufacturer's instructions:

Roundup was applied to bases of trees in the Village and at Site 38 (38 in Fig. 4) to control weed growth. Approximately 30 ℓ (8 gal) was applied in CY-1984. For control of noxious weeds 2,4-D Amine was applied to 8.1 km^2 (2000 acres) in 1984. The areas sprayed were grassy unoccupied areas.

Corn was planted by licensees in CY-1984 on 9.2 km^2 (2268 acres). Licensees are persons who pay the Laboratory for use of a portion of the land on the site for agricultural purposes. Herbicides were applied as follows: 5300 ℓ (1400 gal) of Lasso and 2050 kg (4500 lb) of Aatrex 4L. The application of these was supervised by Fermilab.

Spike 80-W, EPA Registration No. 1471-97, was applied to control weeds around electrical substations, parking lots, hardstand (crushed limestone) areas, air conditioner pads, and service buildings. Approximately 124 kg (264 lb) diluted in 17,600 ℓ (4700 gal) of water was applied to 0.14 km^2

(41 acres) during CY-1984.

For mosquito control, an ultra low volume application of CYTHION Premium Grade Malathion was performed at 12 different times. Approximately 7.6 B (2 gal) of CYTHION were used in each application and the following areas were covered: Village and Sauk Circle just south of the Village (Fig. 1), Sites 29, 38, and 43 (29, 38, and 43 in Fig. 4), the Meson, Proton and Neutrino experimental areas (Fig. 5), and the Industrial Area (Fig. 1).

For control of tent caterpillars (Malacosoma sp.) a 0.14% solution of malathion in water was applied to the foliage of approximately 900 trees throughout the site.

EATON's AC Formula 50, a rodenticide, was placed in pan-type feeders inside approximately 40 outdoor electrical substations to reduce rodent nesting in this high voltage equipment. Approximately 4.5 kg (10 lbs) was used in CY-1984.

The services of a contract exterminator, licensed by the State of Illinois and using EPA registered pesticides, was retained during CY-1984 for the control of miscellaneous pests found in kitchens, laboratories and living areas throughout the site.

3.7.3.2 Polychlorinated Biphenyls

An inventory of polychlorinated biphenyls (PCBs) is maintained. PCB inspections are performed and reports made to the U.S. Environmental Protection Agency as called for in the regulations.[32] The PCB status Report as of January 1, 1984 listed 64 PCB transformers and 2,050 large capacitors in use or storage for future use. These PCB items have been labeled as required. These totals differ from last year's totals because one PCB transformer failed and was properly disposed of and because a number of PCB capacitors were disposed of by incineration in an EPA - approved incinerator.[4] Forty of these PCB capacitors contained exempt quantities of radioactivity. The maximum concentration of radioactivity in the air was calculated based on the gaussian plume diffusion model[16,17] and the wind speeds present on the days when the capacitors were incinerated.[18] The resulting concentrations were less than 1% of the applicable concentration guide.[6]

3.7.3.3 Hazardous Wastes

Significant progress was made during 1984 with respect to identification, collection and disposal of hazardous waste in an environmentally acceptable manner. Responsibility for this program was assigned to the Safety Section in CY-1979 and a hazardous waste handling and storage facility was developed at Site 55 (Fig. 5). This facility is roofed and fenced, has hardstand and two concrete containment areas. An additional facility with concrete containment area for PCBs was developed

at Site 3 where the Environmental Monitoring Station is located (Fig. 5). This facility is for inside storage of hazardous materials which are for future use. In CY-1982 a PCB storage building was constructed at Site 55 which is much farther from the site boundary that Site 3. Off-site impact from a potential airborne release of PCBs was greatly reduced when most of the PCB items were removed from Site 3. In CY-1984 a heated chemical waste storage building was added at Site 55. This facility will have a hood and a indoor shower and eye wash.

Over the years it has been the practice to deposit excess materials such as lumber, concrete, building materials and earth on the Meson Area shielding hill (north of the Meson Lab, Fig. 1) to scatter muons and provide some additional shielding. To assure that none of these materials are hazardous to the environment and none will contribute to the contamination of surface or ground waters, a program to control such deposition was developed during 1979. Rules have been promulgated and responsibility for access and control has been assigned to the Roads and Grounds group. The Safety Section monitors this program. In 1982 burial of wood, paper and other wood products on the hill was halted.

3.7.3.4 Heavy Metals

Copper sulfate is no longer used to treat the ponding systems. There was no evidence of any further impact from the treatment in CY-1981.[33] Copper solution from the etching of printed circuit boards was disposed of as hazardous waste or recycled. Chromate treatment of the cooling towers

has been replaced by biodegradable treatments. Only trace amounts of copper were released in the CUB Tile Field. The copper came from the regeneration of resins used on copper closed loop water systems. Thus, the environmental impact from heavy metals released in CY-1984 should be negligible.

3.7.3.5 Chlorides

The potential environmental impact of release of chlorides from the resin regeneration process into the CUB clay tile field (Fig. 7) has been evaluated. The process uses sodium hydroxide and hydrochloric acid, yielding sodium chloride (salt) and water. Assuming the salt released in one year all ends up in the nearest drinking water well (W1 in Fig. 4) and is diluted in the water normally pumped from that well for one year, the concentration would be less than 25% of the applicable limit of 250 mg/ℓ. See Section 5. Thus, the environmental impact should be minimal. A similar result was found for the impact from salt applied to Fermilab roads in the winter.

4. Quality Assurance in CY-1984

Water samples collected in CY-1984 were analyzed by Teledyne Isotopes, Inc., 1500 Frontage Road, Northbrook, Illinois 60062. In addition, such samples were counted at the Fermilab Nuclear Counting Laboratory. Tritium and ^{45}Ca analyses were done only by Teledyne Isotopes, Inc. since Fermilab does not have the necessary liquid scintillation counting system. Each shipment to Teledyne included at least one sample prepared at Fermilab containing known amounts of several of the accelerator-produced radionuclides. Known concentrations of tritium were included in every shipment.

4.1 Analytical Procedures at Teledyne

Teledyne Isotopes, Inc. analyzes water samples using essentially the same procedures as described previously.[33] Liquid scintillation counting is done using a Beckman Instruments Inc. LS-230 refrigerated system. A 1 mℓ aliquot of the sample is placed in 10 or 15 mℓ of the scintillator "InstaGel," manufactured by Packard Instrument Co., Inc., 2200 Warrenville Rd., Downers Grove, IL. 60515.

The samples were subjected to the appropriate one of the following analyses:

Type 1a: Test for ^{3}H (tritium), ^{7}Be, ^{22}Na, ^{45}Ca, ^{54}Mn, and ^{60}Co at surface water sensitivities. See Table 8.

TABLE 8

Specifications For The Analyses Of
Accelerator-Produced Radionuclides in Water

Radionuclide	CONCENTRATION GUIDE FOR POPULATION Individual (μCi/mℓ)	Suitable Sample (μCi/mℓ)	Community Water System	SPECIFIED SENSITIVITY AND PRECISION* Surface Water (μCi/mℓ)	Ground Water (μCi/mℓ)
^{3}H	3×10^{-3}	1×10^{-3}	2×10^{-5}	3×10^{-6}	1×10^{-6}
^{7}Be	2×10^{-3}	6.7×10^{-4}	1.3×10^{-5}	5×10^{-7}	5×10^{-7}
^{22}Na	3×10^{-5}	1×10^{-5}	2×10^{-7}	3×10^{-7}	2×10^{-8}
^{45}Ca	9×10^{-6}	3×10^{-6}	6×10^{-8}	3×10^{-7}	6×10^{-9}
^{54}Mn	1×10^{-4}	3.3×10^{-5}	6.7×10^{-7}	1×10^{-7}	7×10^{-8}
^{60}Co	3×10^{-5}	1×10^{-5}	2×10^{-7}	1×10^{-7}	2×10^{-8}

* The precision and sensitivity are stated for the 68% confidence level (one standard deviation). The precision required is the value specified or ± 10 percent, whichever is the lesser precision. The sensitivity is taken to be the minimum concentration which can be detected within the 68 percent confidence level.

Type 2a: Test for all of the above at ground water sensitivity plus total radium (the sum of ^{223}Ra, ^{224}Ra, and ^{226}Ra) and total thorium (the sum of ^{228}Th and ^{232}Th).

Type 3a: Chemical separation of ^{45}Ca before its determination; otherwise the same as Type 1a.

Type 4a: ^{3}H only, at surface water sensitivity.

Type 5a: Chemical separation of ^{45}Ca and analysis for ^{45}Ca only, using surface water sensitivity.

Type 6a: The same as Type 1a except at ground water sensitivity.

Type 7a: The same as Type 4a except at ground water sensitivity following distillation.

Type 8a: Test for gross alpha, gross beta, ^{3}H, ^{131}I, and ^{134}Cs at ground water sensitivity. This analysis is performed on Fermilab's one community water system and on other drinking water systems on site which supply water to more than 25 people during the work day.

Type 9a: Test for Sr-90 only, at ground water sensitivity.

Separate analyses of two aliquots from the same sample bottle is indicated by changing the letter "a" to the letter "b" on the Type designation.

The specifications for the above analyses are given in Table 8.

4.2 Quality Assurance Samples

During CY-1984 Fermilab participated in the DOE Environmental Measurements Laboratory (EML) quality assurance program.[34] Results are given in Table 9. Also, Fermilab sent quality assurance samples monthly to Teledyne Isotopes, Inc., who analyzed Fermilab water samples independently. The vendor's agreement with the known concentrations was close to the precision specified by Fermilab (Table 8) except for ^{45}Ca, which is difficult to assay in the presence of other beta-emitting radionuclides. See Table 10.

TABLE 9

Quality Assurance Results for Fermilab

Sample Date	Radionuclide	Percentage of Concentration Guide for Surface Waters* (%)	Prepared Concentration	Ratio of Fermilab Result to Prepared Concentration
5/84	^{60}Co	**	1.64 pCi/g	0.93
11/84	^{54}Mn	136	4.49×10^{-5} µCi/mℓ	0.97
	^{60}Co	**	29 pCi/g	0.96
	^{60}Co	44	4.46×10^{-6} µCi/mℓ	0.99
	^{60}Co	+	0.91 pCi/g	1.07

*Individual in Table 8
**Vegetation Sample
+Soil Sample

TABLE 10

Quality Assurance Results for Teledyne

Sample Number	Radionuclide	Percentage of Concentration Guide for Surface Waters* (%)	Prepared Concentration (μCi/mℓ)	Ratio of Teledyne Result to Prepared Concentration
140	$^{3}_{1}H$	0.17	5.0×10^{-6}	2.8**
	$^{22}_{11}Na$	6.7	2.0×10^{-6}	1.07
	$^{54}_{25}Mn$	0.10	9.5×10^{-6}	1.10
	$^{60}_{27}Co$	14.	4.3×10^{-6}	0.95
141	$^{3}_{1}H$	0.63	1.9×10^{-5}	0.89
	$^{7}_{4}Be$	0.14	2.7×10^{-6}	1.17
	$^{22}_{11}Na$	44.	1.3×10^{-5}	1.07
	$^{45}_{20}Ca$	17.	1.5×10^{-6}	1.30
	$^{54}_{25}Mn$	15.	1.5×10^{-5}	1.06
	$^{60}_{27}Co$	73.	2.2×10^{-5}	1.04
142	$^{3}_{1}H$	0.17	5.0×10^{-6}	0.98
	$^{22}_{11}Na$	6.7	2.0×10^{-6}	1.02
	$^{54}_{25}Mn$	9.5	9.5×10^{-6}	1.01
	$^{60}_{27}Co$	14.	4.3×10^{-6}	0.97
143	$^{3}_{1}H$	0.25	7.6×10^{-6}	0.72
	$^{7}_{4}Be$	0.14	2.7×10^{-6}	1.14
	$^{22}_{11}Na$	37.	1.1×10^{-5}	1.06
	$^{54}_{25}Mn$	20.	2.0×10^{-5}	1.08
	$^{60}_{27}Co$	67.	1.3×10^{-5}	1.04
	$^{45}_{20}Ca$			
144	$^{3}_{1}H$	3.2	9.5×10^{-5}	0.96
	$^{7}_{4}Be$	0.14	2.8×10^{-6}	1.06
	$^{22}_{11}Na$	18.	5.3×10^{-6}	1.07
	$^{54}_{25}Mn$	3.0	3.0×10^{-6}	1.10
	$^{60}_{27}Co$	15.	4.4×10^{-6}	0.92
145	$^{3}_{1}H$	3.2	9.6×10^{-5}	0.93
	$^{7}_{4}Be$	0.21	4.1×10^{-6}	1.10
	$^{22}_{11}Na$	170.	5.0×10^{-5}	1.09
	$^{54}_{25}Mn$	120.	1.2×10^{-4}	1.08
	$^{60}_{27}Co$	290.	8.7×10^{-5}	1.08
147	$^{3}_{1}H$	0.50	1.5×10^{-5}	1.17
	$^{22}_{11}Na$	17.	5.0×10^{-6}	1.11
	$^{45}_{20}Ca$	99.	8.9×10^{-6}	0.61
148	$^{45}_{20}Ca$	99.	8.9×10^{-6}	0.33
	$^{60}_{27}Co$	33.	1.0×10^{-5}	1.04
149	$^{3}_{1}H$	0.05	1.5×10^{-6}	1.57
	$^{7}_{4}Be$	0.18	3.5×10^{-6}	< 0.14
	$^{22}_{11}Na$	4.0	1.2×10^{-6}	0.91
	$^{45}_{20}Ca$	70.	6.3×10^{-6}	0.46
	$^{54}_{25}Mn$	7.9	7.9×10^{-6}	0.77
	$^{60}_{27}Co$	33.	1.0×10^{-5}	0.92

*Individual in Table 8
*Results on undistilled sample

5. References

The appropriate Radiation Protection Standard for penetrating radiation applied to individuals in uncontrolled areas was taken from the DOE Order 5480.1A, Chapter XI.[6] The annual dose for whole body exposure is 0.5 rem when applied to a suitable sample of the exposed population, i.e., individuals for whom the doses can be determined specifically.

The Concentration Guides used in the analyses of the surface water samples for radioactivity were taken from the DOE Order 5480.1A, Chapter XI, Table II, Column 2 (Water in Uncontrolled Areas) and reduced by a factor of three where appropriate for a suitable sample of exposed population, i.e., individuals who cannot be identified specifically in this case. The smaller of the values given for soluble and insoluble forms has been used in each case. The specifications are given in Table 8. The Concentration Guides for airborne activity were taken from the same source, Table II, Column 1 (Concentrations in Air in Uncontrolled Areas), and divided by a factor of three for determining the total off-site potential dose to the public. For tritium the Concentration Guide from Table II, Column 1, is 2×10^{-7} μCi/mℓ. For ^{11}C the Concentration Guide, 2×10^{-8} μCi/mℓ, was taken from the calculations by Yamaguchi.[35]

The Concentration Guide used in the analyses of ground water samples for tritium were taken from the U. S. Environmental Protection Agency regulations for community drinking water systems.[36] The maximum contamination level permitted for tritium is 2×10^{-5} μCi/mℓ and

corresponds to an annual exposure of 4 mrem if one uses the supply as one's sole drinking water source. Note that this is 50 times more stringent than the DOE regulation for a suitable sample of the general population, which corresponds to 170 mrem/year. The Concentration Guides for the other radionuclides in Fermilab's analyses of ground water samples have been determined by dividing the surface water concentrations for a suitable population sample by 50 (Table 8). The specified sensitivity and precision of the analyses have been reduced to well below these Concentration Guides.

The Air and Water Pollution Standards for non-radioactive pollutants were taken from Chapters 2 and 3 of the State of Illinois Pollution Control Board Rules and Regulations.[25] The waters on site were considered to be in the "general use" category. The value for total hexavalent chromium for general water quality is 0.05 mg/ℓ. The Standards for total copper at the discharge point and for general water quality are 1.0 and 0.02 mg/ℓ respectively, for silver are 0.1 and 0.005 mg/ℓ respectively, and for cyanide are 0.025 mg/ℓ for both. The maximum contaminant level for chloride in water for general use is 500 mg/ℓ and the level of total dissolved solids is 1000 mg/ℓ. In public drinking water the maximum levels for chloride and total dissolved solids are 250 mg/ℓ and 500 mg/ℓ, respectively.[37] The Air Quality Standards limit the release for SO_2 and oxides of nitrogen to 816 g (1.8 lbs) and 136 g (0.3 lbs) respectively, per 252 million calories (per million btu's) of actual heat input in any one hour.

The appropriate regulations for PCBs and hazardous wastes are found in the U. S. Code of Federal Regulations 40 CFR 761 and 40 CFR 260-265, respectively. The concentration limit is 2 ppm for human consumption of fish.[38]

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